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Excavation of an early 17th-century glassmaking site ~~in~~ at Glasshouse, Shinrone, Co. Offaly, Ireland

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SUMMARY: An archaeological research excavation was conducted in the area immediately surrounding an upstanding glassmaking furnace near Shinrone, Co. Offaly, Ireland. It dates to the early to mid-17th and was built and operated by French Huguenots, probably de Hennezells (de Hennezel/Henzeys/Hensie) who had settled in this region as part of the Crown plantation of King's County (now Co. Offaly). The de Bigaults [Bigos/Bigoes /Bygoes], who also operated several glasshouses in the county, may also have been involved in the Shinrone glasshouse ~~near Shinrone~~, possibly along with other Lorraine glassmaking families. This ~~wood-fired~~ furnace, which employed wood rather than coal as a fuel~~as opposed to coal-fired furnaces~~, is a very rare survival, with no other upstanding examples known in Ireland, Britain or the Lorraine region of France where these families originated.

INTRODUCTION

The glass furnace at Glasshouse, Shinrone, Co. Offaly in central Ireland, although ~~locally~~ known as such by local people, ~~a glasshouse (pers. comm. Noel McMahon),~~ had until recently remained hidden from the archaeological record.[i] The furnace, which originally would have been within a large wooden shed-like structure known as a glasshouse, is not marked on any map~~s~~, nor is there any contemporary documentary evidence ~~associated with glasshouse~~. It came to the notice of Mary Boydell, former President of the Glass Society of Ireland, in the 1970s when she was editing a reprint of Dudley Westropp's ~~definitive~~ ground-breaking 1920 work on Irish glass. Among Westropp's papers was an annotated sketch plan and elevation of the furnace which had been drawn in 1928 by an informed visitor, ~~whose name appears to have been~~apparently Henry Puie.[ii] Though Boydell did arrange for a magnetometery survey of the glasshouse in the 1970s no further work was conducted until a more thorough magnetometery survey in 1999 (Appendix 1) and the research excavation carried out by the authors (Farrelly and O'Brien) in 1999-~~/~~2001. During the excavation an archaeomagnetic date of 1620-1650 (68% confidence level) and 1610-1660 (95% confidence level) for the last firing of the furnace was obtained (Appendix 2). In 2009, Offaly County Council commissioned 3D laser scanning of the furnace which was undertaken by ~~German company,~~ ArcTron. An interactive aSPECT 3D model of the furnace was produced which can be downloaded along with digital axonometric, and orthographic views of the furnace.[iii] A 3D flash animation video of the furnace can also be viewed or downloaded from ~~this~~ the same website.

TOPOGRAPHY, GEOLOGY AND LAND USE

The glass furnace[iv] is situated in the townland of Glasshouse, 2.3km south-west of Shinrone village which is in the southern part of County Offaly, a land-locked midland county (Fig. 1). The furnace is 70-80m OD above sea level and is located on the eastern-facing slope of a north-south glacial ridge, with a small stream running north-south *c.* 250m to the east, in farmland under pasture. The glass furnace was located on the demesne lands of a levelled 18th-century country house, known as 'Glasshouse', located c. 1~~1~~00m east of the furnace. It was the residence of the Smith family who were granted lands in the adjoining townland of Ballytoran in 1660.[v] On

17th -century maps this area, and indeed much of ~~Co.~~ Offaly, wa~~i~~s depicted as being heavily forested, the predominant native tree at the time being oak. The glasshouse was located at the western end of a 156 acre wood of oak and ash, known as 'Clonliske Wood' (Fig. 2).[vi] Clonliske Wood became Glasshouse townland, the first reference to this new ~~townland~~ name dating~~es~~ from 1717, when Joseph Smith of Glasshouse was listed as witness to a deed.[vii] As timber provided both fuel for the glass furnace and ash for the raw material it was a vital component of glassmaking. ~~To locate~~Siting the glasshouse close to a wood was important in order to avoid transporting ~~wood~~timber, the cost of which was considerable.[viii]

The underlying geology is a thin band of wavy-bedded cherty limestone, thin shale (Ballynash Member) with massive unbedded lime-mudstone (Waulsortian Limestones) immediately north and fossiliferous dark-grey muddy limestone (Ballysteen Formation) immediately to the south. The nearest sources of red sandstone, of which the furnace is composed, are the north-eastern slopes of Devilsbit Mountain, which lies 7km to the south-east, and the south-west slopes of the Slieve Bloom Mountains which lie 12km to the east.

Comment [n1]: I'm not sure if this detail is needed – if not then Ballynash Member, Waulsortian Limestones and Ballysteen Formation could be removed. JF

The natural sand which underlies the site is carboniferous and not suitable for glassmaking. It would appear that good quality silica sand, needed for ~~the~~ glass manufacture, had to be brought to the site, although there is no evidence for ~~where this was~~its source~~d~~. In ~~Co.~~ Offaly there are no known deposits of sand suitable for glassmaking, the closest identified source being at Crannagh townland in ~~Co.~~ Laois, which lies 27.6km east of the glasshouse.[ix]

HISTORICAL BACKGROUND

Indications of glassworking in Ireland before the 17th century are scant, though Henderson and Ivens speculated that glass may have been made in the early medieval period at Dunmisk fort, ~~Co.~~ Tyrone.[x] Historical evidence suggests that glass manufacturing started in Ireland towards the end of the 16th century. The demand for glassmakers in the late 16th /early 17th century appears to be a product of the Crown policy of plantation, where planters establishing new settlements were actively encouraging industrial enterprises in Ireland.[xi] Attracting glassmakers had others advantages apart from the obvious economic benefit of their product. The need for vast quantities of timber meant that large stretches of woodland were cleared:~~,~~ this was beneficial as such places were seen as being dangerous as they were refuges for the Irish who were opposed to the Plantation.[xii]

Huguenot glassmakers became involved in glassmaking in Ireland at this time, having migrated there from Lorraine in France via England (Fig. 3).[xiii] Two glassmaking families in particular, de Hennezells and de Bigaults~~,~~ (~~-~~anglicised to Hensey /Hensie/Henzey and Bigo/Bigoe/Bygoe)~~,~~ appear to have concentrated their glassworking activities in ~~Co.~~ Offaly. Although there is only historical evidence for the Bigos working in ~~Co.~~ Offaly, specifically at Clonbrone, near Birr and Glaster, north-west of Birr, from the 1620s to the 1640s, at the same ~~time~~ period in ~~when~~ which the Shinrone glasshouse was operating.[xiv] ~~The Hennezell family founded the village of Hennezell, Darney, in the Lorraine region of France, where a glassworks was first operated by Jean De Hennezel in 1448.[xv]~~

In 1641 Clonliske Wood, where the Shinrone glasshouse was located, appears to have belonged to John Carroll, an Irish Catholic residing in nearby Clonlisk Castle. He participated in the 1641 Irish Rebellion and subsequent Irish Confederate Wars of 1641-53 against the English Commonwealth.~~.~~[xvi] After the defeat of ~~Irish Catholic~~the Confederate Army ~~in 1653,~~ these lands were forfeited by~~-~~ the English Commonwealth. If the furnace was constructed before the Cromwellian Settlement of 1653 then the glasshouse owners would have leased the lands from John Carroll. After the passing of the Act of Satisfaction in 1653 the forfeited ~~Catholic~~ lands of John Carroll were granted to Thomas Smithsby and Sir William Flower, both Protestants who had supported the English Commonwealth during the Irish Confederate Wars. A portion of these forfeited lands may have ~~then~~ been subsequently leased to Ananias Henzey (born 1618) who is listed in the Census of 1659 (~~recorded~~ though misspelt as Ananias Henley) as the proprietor of 'Bollinure' in the parish of Shinrone.[xvii] Though this placename does not survive as a ~~modern~~ townland name, it is likely to have been located close to the modern townland of Glasshouse, and possibly formed part of Cangort Demesne. The Books of Survey and Distribution, compiled around the year 1700 by the State in an attempt to establish an official record of landowners and their estates, recorded that in 1641 the ~~nearby~~ lands of Cangort and 'Ballynure' were in the ownership of Anthony Atkinson of Cangort Castle. He was a Protestant who participated in the 1620 Crown plantation of this region. A small portion of his estate was located in the townland of Kilcomin which

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may have incorporated the woodland where the glasshouse was established and which subsequently became known as Glasshouse townland. The Henzey family were granted several small estates in the baronies of Clonlisk and Garrycastle around 1653 as part of the Cromwellian Settlement.~~-~~ ~~The Books of Survey and Distribution recorded that ‘~~Annanias Hensey~~’~~ ha~~d~~ving been granted forfeited Catholic lands in the townlands of Barnagrotty and Ballinlough, in ~~the~~ Aghnameadle parish, ~~of Aghnameadle in south Offaly~~ close to the Shinrone ~~glass furnace of G~~glasshouse. During this period another member of the Henzey family, ~~bearing the name of ‘~~Thomas Hensey~~’~~, was granted the forfeited lands of Ballybrack located close to the nearby village of Dunkerrin. In west Offaly near the town of Banagher ‘Josua Henzey’ was granted forfeited lands in the townlands of Milltown, Curraghavarna and Garbally, close to the Bigo glassworks at Glaster. ~~Due to the association of the Shinrone glasshouse with the Henzeys useful parallels can be drawn between glassmaking there and in Staffordshire/Worcestershire at a slightly earlier date.~~

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Ananias was the son of Joshua Henzey who ran Brettell glasshouse in Stourbridge, then in Worcestershire, and was the brother of Joshua and Paul Henzey. In 1649 ~~Ananias~~ he married Catherine, the eldest of Philip Bigo’s three daughters. The Bigos, like the Henzeys, were ~~another~~ a Huguenot glassmaking family with connections in Staffordshire and Worcestershire ~~and~~, who were now based in Ireland.[xviii] It would appear that in 1659 Ananias, listed as ‘Eneas Hensey Esq.’, was the chief tenant of lands owned by his father-in-law in the townland of ‘Kilorney’, near the Glaster glasshouse.[xix] A ‘Hensie’ is also listed in 1659 as living in ~~Miltowne [~~Milltown townland, ~~] in 1659, a townland which is also~~ which is also close to Glaster.[xx] Several of Ananias’s relations, including his nephews Edward and Thomas, and his brother Joshua, had come over to Ireland to assist him at various times~~, including his nephews Edward and Thomas, and his brother Joshua.~~.[xxi] Joshua died in 1668, shortly after he had been granted land near Banagher[xxii]. In 1676, Thomas, who also had been granted land near the Shinrone glasshouse[xxiii] returned to England to work in Stourbridge, as did Edward in the same year.[xxiv]

When Philip died in 1668~~,~~ without a male heir~~,~~ his estate and lands passed to his daughters.[xxv] In 1670 Ananias Henzey set up a glasshouse[xxvi] near the new town of Portarlington, on the border of Laois and Offaly, which was founded in *c*.1660. The Calendar of State Papers for Ireland for November 1670 state that Henzey was 'failing in his art of making glass' due to ‘some disappointment in the melting of his metal’ despite the fact that he had 'practised it in another place these twenty years past'.[xxvii] He appears to have spent a considerable amount of capital on this venture and had ‘occasioned the coming of several families to dwell there [Portarlington]’.[xxviii] It is possible that Henzey was having difficulty in making the transition from wood to coal as a fuel, the latter having become the norm in England by this time. In 1638/9 the export~~ation~~ and manufacture of glass in Ireland ~~had been~~was prohibited and in 1641 another ~~Bill~~ bill prohibited the felling of trees as a fuel supply for glass furnaces in Ireland.[xxix] ~~The~~ This latter prohibition ~~against wood fuel~~ is likely to have been more lax in Ireland where the felling of woodland was still encouraged. It is perhaps more likely that he was trying to produce a clearer glass such as ‘lead’ glass which was introduced in the early 1670s. Despite this setback Henzey must have succeeded eventually as he remained in Ireland until 1695, while also maintaining glassmaking interests in England. In 1695, after the sudden death of his wife, he took over the running of the Great Old Bottle House at Southwark, London.[xxx] It would seem that Ananias’s son, Bigoe Henzey, had taken over the running of the Hawbush Glasshouse~~,~~ in Stourbridge in 1693. However, he returned to Ireland ~~in~~ *c*. 1715 and lived ~~in~~ at Barnagrotty, Co. Offaly until his death in 1733.[xxxi]

It would appear that Philip Bigo ~~came over~~had come to Ireland in 1623 with his father, Abraham. ~~Abraham~~The latter, with his partner, Sir William Clavell, had been running a glasshouse at Kimmeridge in Dorset. [xxxii] Together they had been illegally selling the products of this furnace to the London market, thereby breaking their agreement with Sir Robert Mansell who had a monopoly on all types of glassmaking in England at ~~this~~ the time. Following legal action taken by Mansell the furnace was demolished ~~in 1623~~ by orders of the Privy Council.[xxxiii] ~~Subsequently~~ In the same year Bigo left for ~~Co. Offaly,~~ Ireland, where he leased land at ‘the Castle town and part of the plowland of Clonoghill’ from Laurence Parsons of Birr Castle on the 9th of October 1623. He set up a glasshouse in the adjoining townland of Clonbrone[xxxiv] which included ‘the wood on Clonahill and Commagre’.[xxxv] The lease notes that Abraham was to live close to the Clonbrone glasshouse, in nearby Clonoghil Castle, which was an O’Carroll stronghold damaged during the Elizabethan Wars.[xxxvi] He was also obliged to insert a stone or brick chimney into the castle within a year of taking up his lease.[xxxvii]

Parsons had been ~~hugely~~ heavily involved in, and benefited significantly from, the plantation of the O’Carroll lordship of Éile (Ely O’Carroll) in 1620.[xxxviii] He had been granted 1000 acres of profitable land and 662 acres of wasteland, including wood and bog, centring on Birr Castle which Parsons rebuilt as the centre piece for the re-modelled plantation town of ~~‘~~Parsonstown~~’~~, now Birr.[xxxix] He had already been involved in the Plantation of Munster and the glass industry there through his involvement with his relation Richard Boyle, the Earl of Cork.[xl] Parsons was an entrepreneur with a keen eye on profit, as evident in his condition that Bigo was not 'to set up any glass house or glass work on any other land, or buy wood of any other for his glass work, but only of said Laurence Parsons'.[xli] An account book in the Birr Castle Archives contains financial transactions relating to the Bigo glassworks between 1623 and 1627, from which it ~~would~~ appears that both window and vessel glass were being manufactured. Among the customers listed is Lettice Digby (née FitzGerald), Lady Offaly ~~(Ophaly)~~ who in 1620 had been granted the Barony of Offaly and the manor and lands of Geashill, *c*. 45km north-east of Birr. [xlii] Her purchases include two chests of glass and an inventory of her house in Geashill taken in 1626 lists several glass items, including ‘Ten Venis [Venice] glasses, green glasses seven, aquavite glasses three, a glass…for vineger’ in the buttery, ‘one dozen of glass plates’ in her closet and ‘pieces of window glass’ in the barn,[xliii] some of these items were undoubtedly made at Clonbrone. Bigo also appears to be supplying window glass to Parsons for his rebuilding of Birr Castle. A memorandum of September 1627 states that ‘Roger Foire, glassier’, was contracted by Parsons ‘to colour and putty sufficient all my windows and doors and stairs now made in my English house’.[xliv] The ‘remains of an ancient glass-house, with parts of crucibles and fragments of glass’ ~~was~~ were discovered at Clonbrone by Thomas Lalor Cooke in *c.* 1870,[xlv] but unfortunately ~~there are no longer any visible remains of it~~no visible remains survive today.

In 1627 Abraham surrendered his lease to his son, Philip.[xlvi] Philip appears to have stayed and prospered in Ireland. In 1637 he received a grant of naturalisation where he wa~~i~~s described as ‘Phillip Biggoe (or Bigo), of Birr Kings Co., a native of France’. [xlvii] According to Boate’s *Ireland's Naturall History*, published in 1652, Birr (Clonbrone) provided Dublin with ‘all sorts of window and drinking glasses and such other as are in common use’.[xlviii] By 1641 Philip was living in Newtown Castle[xlix] on his estate lands of Newtown Manor which were located near the village~~s~~ of Lusmagh and town of Banagher in west Offaly (although the lands of Glaster were in the ownership of Garret Moore who lived at nearby Cloghan Castle[l]). In the 1640s Philip

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wa~~i~~s referred to as the 'master and owner of the Glasshouse at Gloaster [Glaster]', ~~which is Glaster townland, near Lusmagh and~~this being the adjoining townland to Ballynasrah in which Newtown Castle is located.[li] According to the Books of Survey and Distribution the confiscated lands of Glaster came into the ownership of Phillip Bigoe ~~in~~ *c*.1660. A large fragment of the glass furnace was recovered from a field wall in ~~Glaster~~this townland, along with fragments of glass found ~~while~~ during field walking.[lii] The glass from Glaster[liii] is of early-mid 17th-century date and ~~later in this report~~below this glass is compared to that produced at Kimmeridge by Philip's father, Abraham ~~Bigo~~. During the Rebellion of 1641 Bigo had been forced to flee ~~Co.~~ Offaly and his brother-in-law, Jacob Dehooe (du Houx), was killed in the conflict.[liv] There are indications that Bigo resumed glassmaking after the ~~rising~~rebellion, as according to Symner, writing ~~in~~ *c*. 1650, 'Bego a french man here made before the warr very good glass and of all kinds in the Kings County, and now [for] the Lord President of Connaght Sir Charles Coote Esq. he hath for this 3 years don[e] so againe but none so fine are now made more …'.[lv] There are the remains of a glasshouse[lvi] south-west of Tullamore which ~~is simply~~was referred to in 1654 as 'The Glasshouse of Bonneturrin'.[lvii] The Books of Survey and Distribution in 1641 list~~s~~ Sir Charles Coote as the owner of lands in the townland of Ballynacanty, which is 3.5km south-east of the glassworks at Bunaterin. It is likely, given Coote's connection with Philip Bigo, that Bigo ran the this glassworks ~~at Bunaterin~~.

Despite the numerous historic glassworks in ~~Co.~~ Offaly there is only one intact glass furnace surviving. Normally a wood-fired furnace has a short lifespan, as after a few years the intense heat causes the structure to become unstable. The fact that the furnace near Shinrone is still upstanding suggests that the glasshouse was abandoned quite abruptly, perhaps because of the 1641 Rebellion and the subsequent Irish Confederate Wars of 1641-53, which saw native Irish Catholics taking arms against English Protestant settlers. Its fortuitous~~continued~~ survival ~~is fortuitous and~~ may also be due to its incorporation in the ~~private~~ demesne grounds of an 18th-century country house, known as Glass House, built by the Smith family. No doubt its appearance as a rustic grotto, with a blue glazed interior, was viewed as an attractive landscape feature ~~which was~~ worth preserving.

THE UPSTANDING FURNACE

Comment [LM2]: And were replaced by coal=fired ones?
Reply [JF]: Not in Ireland as far as I know. Coal-fired furnaces tend to be located at ports where coal could be imported from England as there are limited coal sources in Ireland and these tend to be of poor quality. I think the article is long enough without going into the transition from wood to coal which does not really relate to this article.

Comment [LM3]: As per reviewers comments – is there any information about what happened to the original family?
Reply [JF]: Not sure what you mean by the original family? As per discussion above the ownership of the land on which the glasshouse stood in the early 17th century is unclear as the townland name did not exist then and the possible owners are discussed. The Smith family do not appear on the scene until much later when the glasshouse was abandoned.

THE STRUCTURE

The furnace was built from red sandstone and is a vaulted structure 3.3m high with walls 0.8m thick (Fig. 4). The roof of the furnace chamber consists of a barrel-vaulted arch constructed of roughly wedge-shaped voussoirs. There are two platforms, know as sieges, on which the crucibles rested. E~~e~~ach siege is *c.* ~~about~~ 0.7m high, with one on either side of the fire trench or flue, and ~~(Fig. 5). Each siege~~ held two crucibles, the imprints of which, 0.4m in diameter, are still visible (Fig. 5). ~~Each~~ Both ends of the fire trench ~~finished~~ terminate with an arched opening, from which the vaulted superstructure had been constructed. The sidewalls, now missing, were probably constructed from quartz-tempered handmade clay bricks as large numbers of these were found around the site, some with glazed surfaces similar to ~~the rest~~that of the furnace interior. These walls could have been demolished and rebuilt in order to remove or replace the crucibles. It is possible that the external surface of the furnace roof and side walls ~~were~~ was coated in a layer of mud mixed with lime mortar that may have acted as an insulating layer. Working or gathering holes, two in each side, for removing glass from the pots and reheating glass as it was worked, would have been incorporated into these brick-built walls. Although no evidence for the size of the gathering holes was found at the Shinrone furnace, a square cover for a working-hole found at Bagot's Park, Staffordshire, the site of an early 16th-century furnace, was 0.2m across.[lviii]

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Comment [LM4]: Is this a comparable? Does this need stated?
Reply [JF]: It is a similar furnace in plan so I think it is interesting to give this information.

The Shinrone furnace had no chimney but there were five holes high in the surviving walls of the furnace, each about 0.18m wide, three in one face of the vault and two in the other. Comparisons can be drawn with post-medieval, wood-fired pottery kilns with domed superstructures, for which experimental replicas have been constructed containing a series of small vent holes in the dome, without a chimney, and these have operated successfully.[lix] The vents allowed smoke to escape and g~~i~~ave better control of the atmosphere within the kiln or furnace. The flue at Shinrone varied in width from 1m at one end (the south-west end shown to the right of Fig. 5) to 1.8m at the other, suggesting directionality in its use. It was 5.5m long. The blue glaze which coats the interior was produced unintentionally through the reaction of the silica-rich sandstone of the furnace with the potash-rich ashes and vapour from high temperature dissociation of potassium carbonate in the ashes of the wood fuel, which ultimately resulted~~s~~ in droplets of transparent blue glaze or ‘kiln sweat’ falling from the furnace roof and walls.[lx]

The temperatures likely to have been attained at Shinrone and Glaster have been estimated by comparison with experimental data gathered for glasses of similar composition to those produced at Shinrone (see Table 1) and waste products associated with those glasses. The melting temperature of the glass-working waste, such as the lumps and dribbles, and ~~also~~ of the glass products from Shinrone, is estimated to ~~be in the region of~~have been *c.* 1260-1290°C, and therefore the temperature attained in the furnace may have exceeded this slightly. The crucibles from Shinrone, when~~By~~ ~~comparison~~ compared with ~~crucibles~~ those of similar composition from Kimmeridge, which were tested to destruction, ~~the Shinrone crucibles~~ would probably have started to lose their strength and shape at about 1550-1600°C. The same crucibles were examined for evidence of the temperatures that they experienced during use, and the estimates were 1300-1350°C for Kimmeridge. [lxi]

It is curious that the furnace at Shinrone wa~~i~~s operating as a continuation of a long medieval tradition at a time when new technological innovations were being explored in England, most notably at Kimmeridge where Abraham Bigo was directly involved. It could be postulated that the Kimmeridge furnace, with its winged shape and deep central flue, was the product of the extensive financial resources at the disposal of Sir William Clavell, as well as the~~a~~ necessity ~~in~~ of coping with the technological challenges of burning oil shale. The glassmakers in ~~Co.~~ Offaly were likely to be self-financing and moreover had an abundant supply of traditional wood fuel. Interestingly, there is a striking similarity between the construction and design of the furnace at Shinrone ~~with~~ and the well known example at Bishops Wood, ~~in~~ Staffordshire. This is located in the same parish where the first Bigos in Staffordshire, Anthony Bigo and his wife Ann, ~~are~~ were recorded as living in 1612-13.[lxii]

THE EXCAVATION

An archaeological research excavation was conducted over ~~six weeks in~~a total six week period between 1999 and 2001 in the area surrounding ~~the upstanding~~a glass~~making~~ furnace. ~~In all 11~~ Eleven cuttings were opened, comprising a total area of 157m^2 ~~were opened~~ (Fig. 6). A magnetic gradiometry survey of an area 40m x 40m, roughly centring on the furnace, had been carried out prior to excavation and had shown several strong magnetic point sources (Appendix 1). The most southerly

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cutting (Cutting 1) was opened to investigate one of these anomalies ~~which was~~ 15m south-west of the furnace.~~,~~ ~~h~~However, an 18th/19th-century iron barrel~~-band~~ hoop was found to be the source of this strong reading, and any ~~material culture~~artifacts found ~~incidentally~~ in this cutting, including a quantity of glass bottles, appeared to post-date the glassmaking period. The main cuttings were immediately to the west and north of the furnace, with trenches extended in the direction of all the cardinal points in order to ascertain the outer limit of the glasshouse.

THE LEVELLING DEPOSIT (PHASE 1)

The earliest archaeological deposit consisted of a grey carboniferous sand layer [~~(~~C84~~)~~]. It had the appearance of a natural sub-stratum~~a~~ except that it was found to contain small fragments of window glass. This layer was found beneath the majority of archaeological features and deposits, and it seems likely that it was intentionally spread to act as a levelling deposit in order to provide a suitable surface for later activity.

PHASES PRE-DATING THE UPSTANDING FURNACE (PHASE 2)

Cutting 3 (see Fig. 7)

South-west of the furnace, and upslope, the stratigraphy was over 1m deep and consisted of layers of fire-reddened sandy clays [~~(~~C65/C27/C83~~)~~], possibly re-deposited. A later wall [~~(~~F3~~)~~] cut~~s~~ through these layers, as ~~does~~ did a pit [~~(~~F16~~)~~], *c*. 3m wide by 0.29cm deep, which wa~~i~~s full of debris [~~(~~C57~~)~~] including crucible, brick and furnace fragments. This debris belong~~s~~ed to a previous phase of activity, ~~thus~~ indicating the existence of an earlier furnace. ~~This~~ The pit was sealed with a layer of mortar [~~(~~C63~~)~~]. Beneath the fire-reddened clay were thin layers of charcoal-rich sandy soil containing window glass, brick fragments and glass waste [~~(~~C68/C75/C76/C82/C89~~)~~], a small deposit of fine grey sand [~~(~~C93~~)~~] and a small area of yellowy-red silty sand [~~(~~C71~~)~~] with no finds.

PHASES CONTEMPORARY WITH THE UPSTANDING FURNACE (PHASE 3)

Cutting 2 (see Fig. 5)

In the vicinity of the furnace, immediately beneath the surface, there was a large scatter of debris [~~(~~C12~~)~~] including furnace and crucible fragments and bricks. Below the debris were small patches of internal flooring consisting of small stones in a mortared floor [~~(~~C16~~)~~] and a compact stony layer [~~(~~C10~~)~~] overlying a layer of fire-reddened clay [~~(~~C27~~)~~]. North-east of the furnace there was a layer of grey sandy ash [~~(~~C21~~)~~] and light grey sandy clay [~~(~~C36~~)~~] which may have been contemporary with the furnace. Immediately north of the firing trench was an area of fire-reddened clay [~~(~~C14~~)~~], which was archaeomagnetically dated (Appendix 2). The fire-reddened clay appears to have cut through a thin layer of mortar [~~(~~C95~~)~~] and the underlying natural subsoil. At the other end of the fire trench were two shallow, flat-bottomed pits within a portion of the mortared floor (Fig. 6). The larger, roughly circular pit [~~(~~F6~~)~~] measured 0.92m x 1.3m and was 0.4m deep;~~ and~~ the smaller ~~(~~[F7~~)~~] circular pit measured 0.6m in diameter and was 0.2-0.8m deep. Both were filled with silty clay which had flecks of fire-reddened clay [~~(~~C17 and C23~~)~~]. These pits may have acted as supports for circular barrels used by the glassmakers, ~~for example~~perhaps to collect waste glass, or as water containers. The receptacles may have already been in position when the floor was laid, though it is more likely that these depressions were deliberately created in the floor for the receptacles. The mortared floor, wherein the pits were contained, ~~overlies ~~overlay a layer of silty sand with high quantities of fire-reddened clay ~~(~~[C27~~)~~].

Cuttings 3 and 4 (see Figs 5 and 7)

The stone foundation of a wall ~~(~~[F3~~) ~~] was discovered in Cutting 2 in the first season of excavation, and was followed later in Cuttings 3 and 4. In the eastern extension, Cutting 4, the wall extended 1m into the cutting before terminating. There was no posthole at the terminal to suggest that this had been the entrance. ~~and t~~The wall trench~~,~~ contained a sandy fill ~~(~~[C62~~) ~~] over mortar [~~(~~C96~~),~~] and did not reappear in the remaining 3m of the cutting. In fact the stratigraphy in the rest of this cutting was very shallow, with a thin layer of mortar ~~(~~[C49 and C55/C56~~) ~~] appearing between the ~~turf ~~sod layer and the natural subsoil. The wall trench continued upslope through the western extension, Cutting 3, where it remained a consistent 0.9m wide and 0.15m deep. The wall foundations were cut into an earlier build up of fire-reddened sandy clays ~~(~~[C65 and C27~~)~~]. The wall appeared~~s~~ to belong to the last phase of activity on the site, contemporary with the upstanding furnace. This wall is likely to have been a sidewall of the glasshouse as there was evidence of collapsed rubble and roof slates on ~~the ~~its external south side~~ of the wall~~. The clay layer south of the wall wa~~i~~s very compact [~~(~~C41~~)~~] and there wa~~i~~s a patch of mortar [~~(~~F8~~)~~] with a smooth surface, ~~which is~~ perhaps representing the partial survival of a mortared floor.

Cuttings 10 and 11 (see Figs 8 and 9)

South-west of the furnace, in Cutting 11, a stone feature [~~(~~F15~~)~~] running east-west, parallel to and contemporary with the wall foundation ~~(~~[F3~~)~~], was uncovered. South of this feature ~~there i~~was a grey ash-like deposit [~~(~~C92~~)~~] with charcoal inclusions. Cutting 10 was opened further upslope to the west to ascertain how far the ~~site~~ glasshouse extended in this direction. As with Cutting 11, time constraints mitigated against this cutting being fully resolved, however, a lot of scattered stones were uncovered 0.25m beneath the sod and seem to be suggestive of a collapsed wall ~~(~~[F12~~).~~]. These wall foundations ~~indicate~~ suggest that the ~~site~~ glasshouse extend~~s~~ed at least 16m west of the upstanding furnace.

Cuttings 6, 7 and 8

Downslope, to the east and north of the furnace, the stratigraphy was very shallow. An irregular linear feature ~~(~~[F-11~~)~~] running east-west was found in Cutting 6, and Cuttings 7 and 8 to the west and east respectively were opened to follow this feature. However, in both cuttings this feature terminated. Though it was 3m from the area of intensive burning ~~(~~[C14~~)~~] at the northern mouth of the furnace, it is possible that this was a slot trench (0.2m deep) for some form of fire-screen wall (3.7m long), probably ~~wooden~~ of timber (Fig. 5). Excavation of the medieval glasshouse at Blunden's Wood, Surrey, revealed evidence of a screen wall located 0.6m to the north-west of the hearth of one furnace.[lxiii] This linear feature had a fill of sandy clay ~~(~~[C67~~)~~] and was cut into the natural sandy subsoil, which appears to have been the internal floor of the glasshouse. A thin layer ~~(~~[C66~~)~~] containing red and yellow brick fragments ~~overlies~~ overlay this feature.

Cuttings 9, 12 and 13

The stratigraphy in Cuttings 9 and 12 was very shallow, with a layer of stones and debris beneath the ~~turf~~sod, and a layer of mortar beneath ~~(~~[C61~~)~~] (Fig. 6). Most of the mortar had a flat surface on ~~a least~~ one side and in some cases on both sides. As there was no trace of a collapsed wall, it seems likely that this may have formed an area of hard internal flooring. In Cutting 9, this mortar layer simply terminate~~s~~d 9.5m from the upstanding furnace where it ~~meets~~ met a crudely cobbled surface ~~(~~[C85~~),~~], possibly an external yard. Both the mortar and cobbled layer ~~lie~~ lay on top of the levelling deposit.

Although there was evidence for at least one sidewall to the south of the furnace, mentioned previously, no wall foundations were found to the north and east, which suggests that the building may have been open on these sides. The area to the north-west was largely unexcavated, with only one small trench (Cutting 13) opened~~,~~ which, beneath the ~~turf~~ sod, contained a layer of fine gravel with slate fragments over lumps of mortar, similar to that found in Cuttings 9 and 12.

Cutting 5

There are several undulations in the area surrounding the glasshouse and there was speculation that these may be mounds of glassworking debris or cullet. One of these low mounds, 14m north-east of the furnace, was investigated (Cutting 5), but ~~and~~ proved to be archaeologically sterile.

PHASES POST-DATING THE UPSTANDING FURNACE (PHASE 4)

Cutting 3

After the furnace was abandoned the wall ~~(~~[F3~~)~~] to the south was robbed out and the fill ~~(~~[C62~~)~~] of the wall trench was covered by a gravel layer ~~(~~[C58~~)~~] up to 0.25m thick. A layer of glassmaking debris ~~(~~[C12/C47/C59/C86~~)~~] overlying much of the site signifies the demise of the glasshouse at this location.

THE GLASS

During the course of the excavations at Shinrone just over 24.7 ~~kilos~~ kg of glass were recovered (Fig. 10), which was scientifically analysed,[lxiv] and studied typologically.[lxv] The analytical methods used are ~~given~~ set out in Appendix 3. Due to extreme weathering 0.17~~-~~kg of glass could not be positively assigned to type ~~due to extreme weathering,~~, although most fragments are likely to be Shinrone glass. Some 0.47~~-~~kg of glass is considerably later in date and it is no surprise that all fragments were found in Phase 4 contexts or the topsoil. The remainder of the glass was probably made elsewhere and brought to the site in the 17th to 19th centuries. In addition a small assemblage of 53 fragments of glass from the nearby 17th-century glasshouse at

Glaster, recovered by field walking, was examined and compared to the Shinrone assemblage.

These categories of glass are discussed in turn below. The average compositions ~~for~~ of each of these groups are given in Table 2. This data is discussed in more detail later in this paper, but it is important to note here that the composition of the glass made at Shinrone is distinctive and identifiable. This particular composition contains higher levels of lime than earlier potash glasses and re~~oc~~curs frequently amongst glassworking waste as well as fragments of products from the site. Similarly the composition of glass made at the nearby Glaster furnace has been identified by analysis. The Shinrone and Glaster furnaces ~~are~~ were close to each other and broadly contemporary: ~~and so~~ the glass made at each is very similar, but not completely identical. The Glaster glass contains slightly lower concentrations of manganese, phosphorus, aluminium and iron oxides. This difference in composition provides assurance that analysis would identify any glass brought to either site from elsewhere, for example as cullet for recycling in the glass batch. Further, although the glass from these Irish sites is broadly similar to contemporary glass made in England, there are important and consistent differences. The Irish glass contains lower concentrations of phosphorus and manganese than the English equivalents, enabling easy identification of the Irish glass at the site.

GLASS MADE AT SHINRONE

The majority of the glass, 19.82 kg in total, is a pale green ~~HLLA~~ glass type (shown as Mixed 1 in Fig. 10), with surface iridescence caused by weathering. It contains higher levels of lime than earlier potash glasses and so is often referred to as High Lime Low Alkali (HLLA) in the scientific literature. As most of this is in the form of working waste it is clear that it was made at Shinrone. This glass is typical of domestic production in the British Isles during the late 16th and 17th centuries.[lxvi] Glassmakers used a variety of locally grown plant ashes in the batch and these, as well as natural impurities with the silica sources, gave the glass a typically green hue. This glass was found in many contexts across the site (Table 3). It is particularly abundant in the Phase 2 levelling context (27), and is also present in a smaller, but still significant quantity in the Phase 2 pit fill (57) (Fig. 11).

The glassworking waste can be divided into undiagnostic waste, such as lumps and threads of glass, hot working waste, including evidence of blowing, and cold working waste. Undiagnostic waste is found on all glassmaking sites, most commonly in the form of lumps, runs and other accidental spillages, and it can be useful for establishing the type of glass being made at the site. Some of it is chemically altered, however, through reactions with the crucibles, furnace structure or fuel ashes but this is generally apparent by changes to the colour or opacity of the glass. Working waste, both hot and cold, is much more informative for a number of reasons. It consists of fully ~~-~~formed glass that was being used to make the final product, and is therefore ideally suited to comparative analysis with finished items. In particular blowing waste is useful as it not only demonstrates glassworking techniques, but ~~it~~ can also indicate ~~what~~ the output of the furnace ~~was~~, even if there are no extant fragments of the finished products.

The survival of blowing waste is rather more haphazard to locate archaeologically, as it was a valuable by-product that the glassmaker would usually re-melt if possible. On some sites it is virtually absent, whilst on others it is found in relative abundance. For example, at John Baker's furnace at Vauxhall in an assemblage of 2.7kgs of glass waste only one moil was present,[lxvii] whilst the glass assemblage from Sir Robert Mansells' Austin Friars furnace contains a significant quantity of blowing waste and even half-formed vessels.[lxviii] Fortunately, at Shinrone a large assemblage of working and blowing waste is identifiable.

BLOWING WASTE

Moils

The most common form of working waste at Shinrone is the moil, and 72 can be identified (Table 4). A moil is the glass that adheres to the blowing iron when it is dipped into the crucible to take a gather of glass, and therefore ~~it~~ is the one type of working waste always produced when glassblowing is taking place, irrespective of the output. Once the object is fully formed and removed from the blowing iron, the moil remaining on the iron, which is now cool, is broken off.[lxix] Due to their direct contact with the iron, moils have a number of very distinct features. They have a slightly roughened inner surface from contact with the iron, they are often thinner further away from the end of the iron and at Shinrone they are never found whole, probably due to the way they have been removed. Interestingly, almost all the moils found at

Shinrone have a slightly concave inner surface, indicating that the tip of the blowing iron was bulbous, a feature that is sometimes shown in contemporary illustrations.[lxx]

The moils from Shinrone are all fairly uniform in shape (Fig. 12)~~,~~ and, without exception, all occur in the same HLLA glass. They are found in a variety of contexts and in all phases, without any obvious pattern to their distribution or chronology, which is not surprising given that moils must have been formed in all periods of glassmaking. One interesting variation is their internal diameters, which corresponds to the external diameter of the blowing iron. Although many are too fragmented or distorted to be recorded accurately, it is possible to measure most examples and these reveal an interesting variation which has ~~never~~ not been previously observed in an assemblage from a medieval or post-medieval site (Fig. 13).

Where possible, the internal diameters of all moils are measured to the nearest 2.5mm~~,~~ and, as the moil's inner surface is often slightly concave, this is taken at the widest point. Two clusters emerge, the majority falling into the group which peaks around 22.5-25.5mm, with a second group peaking at 42.5mm. Fragments of blowing irons have been occasionally found at glassmaking sites, such as one from the 17th-century furnace at Kimmeridge, Dorset which had an end diameter of around 30mm.[lxxi] These show that, unlike modern blowing irons that are made from cast steel pipes, earlier irons were made by rolling sheets of iron to form a tube. Consequently, each would inevitably be slightly different in size, but the fact that the moil diameters show two distinct peaks, rather than a continuous range, indicates that there are fairly standardised sizes of iron in use at Shinrone. This variation is not linked to period (see Table 4), and therefore is more likely to relate to the type of item being blown. Given the relative proportions of window to vessel fragments found, this might suggest that the larger blowing iron was used for vessel glass and the smaller for window~~s~~ glass, although this is not certain.

Over blows

The other distinctive form of blowing waste found at Shinrone is the over blow (Table 5). An over blow is the portion of glass that lies between the blowing iron and the finished item.[lxxii] As almost all vessel~~s~~ and window~~s~~ glass ~~have~~ has a diameter that is wider than the blowing iron it is almost impossible to form ~~them~~ it without a section of excess glass occurring. Consequently over blows ~~are~~ usually taper~~ing~~ in shape, and are frequently misidentified on sites as portions of bottle necks or simply as ‘tubes’.

However, they are usually too thick for this and are easily distinguishable by the presence of many large and elongated air bubbles, and a circumference that is often irregular, caused by the way they are roughly removed from the blowing iron.

As with moils, over blows were usually recycled back into the batch, and the presence of over twenty at Shinrone is unusual. Another similarity with moils is their presence in a wide variety of contexts and in all phases. It is not normally possible to tell what specific objects were being blown from the over blows alone. However, the over blows from Shinrone fall into two distinct types~~,~~: those that are very thick and taper out significantly (Fig. 14 OB1-12), and those ~~which~~ that are thinner and narrower in diameter (Fig. 14 OB13-28). Given their size, it seems that the former type must relate to cylinder glass production, whereas the latter are likely to have come from the production of smaller vessels.

Other blowing waste

The final observation to make concerning the blowing waste concerns those types that are not present in the assemblage, and what this indicates about vessel production at Shinrone. The fact that ~~just~~ only moils and over blows were found suggests that only simple vessels constructed from a single paraison, or bubble of glass, were made. Indeed, paraison ends that result from the formation of multiple part vessels, such as stemmed glasses, are totally absent, as are decorative canes and other waste found at sites where better quality soda glass was being worked. These general observations concerning the waste of the furnace are further confirmed by the evidence of the vessels found on the site.

COLD-WORKING WASTE

A significant quantity of cold-working waste from window glass production, taking the form of trimmed edges, was found at Shinrone (Fig. 15). These are clearly the straight, cut edges from cylinder glass production, rather than the curved edges from crown glass manufacture. ~~Not only can t~~This can be seen, not only in their form, but also in the parallel alignment of rows of elongated air bubbles present within the glass. When glass cylinders were blown and the over blows from either end removed, the remaining tubes of glass were folded out and flattened whilst still warm, before being allowed to cool. Their edges were then initially prepared by cutting off any excess or rough portions with a pair of shears~~,~~ and, as with most other forms of working waste, ~~this~~ would usually be recycled.

OUTPUT OF THE FURNACE

The blowing waste shows that both window and vessel glass was produced at the furnace, and this is also clear when the assemblage of wastes is examined. Although quantifications are fairly meaningless when dealing with this type of material, it appears that window glass makes up the majority of the glass found ~~throughout~~ in all periods at the site (Fig. 16). Indeed, due to its often greater thickness there is a significant bias towards vessel glass in this distribution, and it seems likely that the furnace was ~~primarily~~ mainly used for making window~~s~~ glass, and that vessel production was probably a small, if profitable, sideline. The one difference is that there is a significant increase in vessel fragments during Phases 3 and 4 of the operation, perhaps in response to a growing demand for certain forms that were becoming popular from the mid-17th century onwards.

Window Glass

Fragments of window glass made in Shinrone HLLA glass were found in almost all depositional contexts (Table 6). The window glass has been quantified, not only by weight, but also by surface area.[lxxiii] ~~Both m~~Measurement by both weight and surface area shows that the largest single group of window glass came from the Phase 2 levelling context (27), although Phase 1 contexts (68, 82, 83 and 89), and Phase 3 contexts (72 and 81) also contained significant assemblages. In contrast, window glass from final Phase 4 was found in smaller, more dispersed quantities. However, despite these differences, and just as with the working waste, there seems to be no significance in the distribution of the window glass across the site to indicate zones of working or later preparation.

Vessel Glass

Although a small amount of diagnostic vessel glass made in Shinrone glass was recovered, the majority took the form of small pieces of curving body which could have come from a wide variety of different types of small bottles, flasks, jugs or even drinking vessels. Nonetheless, sixteen fragments are sufficiently large, or ~~more~~

distinctive, to enable proper identification (Fig. 17). The most prevalent form, with up to seven different examples, GL1-7, is the small spouted jug or cruet. GL1 is a complete base and GL2 a portion of base-ring, demonstrating how their footed form is constructed from a single paraison of glass. GL3 is an interesting fragment of body and lower spout that has become ~~heat~~ distorted by heat and compressed, whilst GL4 and GL~~-~~5 are ~~both~~ sections of body that have the lower attachments from applied handles upon them. The last two pieces are not quite so diagnostic, but are likely to ~~also~~ have also come from small jugs. GL6 is a lower tapering portion of neck, too long to have been from a contemporary bottle, and GL7 a heat-distorted rim, everted in the fashion of a jug. This type of jug or cruet made in a mixed alkali glass is not a particularly common form, although, interestingly, a distorted spout from one was found at the furnace at Kimmeridge,[lxxiv] and the form is usually dated to the first half of the 17th century.[lxxv]

Another form that is typologically similar to the spouted jug, when fragmented, is the small bottle. Four examples were recovered at Shinrone. GL8 is a small near-complete cylindrical base~~,~~ which, unlike the jug, does not have a folded base-ring, whilst GL9 is a more fragmented example ~~which is heat~~ distorted by heat. GL10 is another base, but ~~this one~~ is square in cross-section, and the final fragment, the rim GL11, could have come from either style of bottle. This type of container first ~~appears~~ appeared in the later 16th century, but ~~increasingly~~ became increasingly popular during the 17th century, in which context ~~when~~ they are found in most domestic assemblages.[lxxvi]

The remaining vessels are slightly more surprising in their presence at Shinrone. The first, GL12, is the rim from a large thick jar~~,~~ and, although made in a light green mixed alkali glass, ~~it~~ is of a type more normally dated to the later 17th century, when it wa~~i~~s usually found made in a dark olive glass. Likewise, similar observations can be made about fragments from four light green wine bottles GL13-16, which are discussed further below. GL13-14 are thick bases from the shaft and globe variety, a type usually dated to around 1650-80. Two rim or neck fragments, GL15-16, are slightly less diagnostic but are almost certainly from the same type of bottle (Fig. 18).

Eleven samples of vessel glass were subject to analysis using a scanning electron microscope (SEM) with an energy dispersive x-ray spectrometer (EDS), and additional analysis was ~~also~~ undertaken using X-ray fluorescence spectroscopy

(XRF), (methods are outlined in Appendix 3). The results~~,~~ (Table 9 in Appendix 3), not only demonstrated that there was compositionally very little difference between the individual vessels, but also that they were indistinguishable in nature from the analysed working waste found at the site.[lxxvii] The attribution of a firm provenance of the vessels to Shinrone, and the shaft and globe wine bottle forms in particular, is highly significant. The exact origin of the form is uncertain, but the earliest datable example is a seal, stamped with 1650, found on the Thames foreshore.[lxxviii] However, proving that these fragments were manufactured at Shinrone~~,~~ makes this is an important find, as it shows that the furnace was producing what would have been ~~at the time~~ an extremely innovative form at the time. It is unlikely that the inventor of the wine bottle will ever be identified for certain, but the similarity between the early examples dating to 1615-23 from Kimmeridge and~~to~~ those from the Shinrone glasshouse~~ near Shinrone,~~ would suggest that Abraham Bigo, or his son Philip, may have been developing this form, perhaps in collaboration with the Henzeys, either of whom were likely to have run the Shinrone glasshouse.

GLASS RECOVERED FROM SHINRONE BUT MADE ELSEWHERE

WINDOWS

There are 0.31~~-~~kg of glass with a lighter more aquamarine colour and virtually no surface iridescence. This type is typical of mixed alkali glass (shown as Mixed 2 in figs 10 and 11) dating to the later 17th or even 18th centuries, which contained larger levels of soda. This mixed alkali glass, although often found in very small quantities, is present in many contexts across the site.

Most of this glass contained higher levels of soda and magnesia, but less manganese, than the Shinrone glass, which suggests that it was not produced at Shinrone, an observation which is confirmed by the typological analysis of the glass. This mixed alkali glass has a more stable composition so has not weathered to any visible extent. The high (~0.4wt%) levels of strontium detected suggest that it was made using ash from kelp, ~~which is ash from~~a form of seaweed. Kelp was used in some English glass from the 17th century but only becomes common in English window glass from the beginning of the 18th century.[lxxix]

In the first two phases there is very little of this kelp glass and it is therefore possible that those few grams that do occur are archaeologically intrusive or might have been misidentified. In the third phase there are 38g of mixed alkali glass and this rises to 138g in the final phase. Almost without exception all of this mixed alkali glass is in the form of prepared window pane fragments. There are no pieces of working waste present, ~~which~~ confirming that~~s~~ the glass was brought onto the site fully formed. The fact that it is only found in the last two phases of operation at Shinrone, coupled with it stylistically and compositionally ~~-~~belonging to the later 17th century or ~~after~~later, suggests that its presence is coincidental and might even post-date the operation of the furnace.

VESSELS

The remaining glass, 4kg in total, making up 16% of the assemblage, is a dark green/brown colour typical of later 17th- and 18th-century wine or case bottles. These were made from similar HLLA glass but they contained more alumina, iron oxide and often magnesium and barium, but less potash and often phosphorus, relative to the glass made at Shinrone. The higher iron content and greater thickness of these fragments accounts for their strong colour.

When measured by weight this glass is overrepresented due to the much thicker walls of the bottles, and in reality it was far less frequent that the quantification suggests. Whilst much of this dark bottle glass was found in the topsoil or Phase 4 contexts, suggesting it post-dated the furnace, a small amount did occur in Phase 2 and Phase 3 contexts. Given the total absence of any similar dark waste it was obviously ~~was~~ not made at Shinrone, although some might have been used by those working there.

Four fragments of pale olive vessel glass from the site were found to be compositionally similar to the bottle glass, although they contained slightly less iron, manganese and barium. This glass is also distinct from the Shinrone glass and was not made at the site.

GLASS MADE AT GLASTER

Glass from Glaster is consistent in appearance, and very similar both visually and in its weathering to the glass produced at Shinrone, although it is even lighter in colour. All of this glass had similar HLLA compositions (average compositions in Table 9,

Appendix 3) but can be distinguished from the glass made at Shinrone as the ~~Glaster~~ former glass contains very slightly lower concentrations of manganese, phosphorus, aluminium and iron oxides.

The majority of the glass fragments from Glaster consist of various types of working waste. There are twenty-~~-~~one small lumps, pulls and dribbles, which in themselves are relatively undiagnostic, except that they~~for~~ ~~indicating~~ indicate that production was taking place on site, plus some chemically altered waste. However, amongst the waste are eight fragments that almost certainly are parts of moils. Although none of their internal diameters can be accurately measured, it would appear that they all fall into the smaller range of 20-30mm as found at Shinrone (Fig. 13), suggesting that they resulted from vessel rather than window glass manufacture. Furthermore, there are also portions from two over blows, and again these are too small to have come from cylinder glass production and must be associated with the manufacture of small vessels. In addition to the working waste, there are some fragments of possible products from the furnace. Five of these appear to be from vessels~~;~~: four ~~being~~ are curved portions of fine body from small bottles or flasks, and one is a possible distorted spout. There are, however, no fragments thick enough to have come from larger flasks or bottles, similar to those seen at Shinrone.

The remaining fragments are all from window glass. Ten are thin plain portions, but there are two sections of cylinder edge, suggesting their method of manufacture.

In summary, the glass assemblage from Glaster, ~~whilst~~ while small in size, is relatively informative. It is clear a similar HLLA glass was used, and that the output of the furnace was very similar to Shinrone~~;~~, consisting of both small vessels, such as bottles and simple tablewares, ~~as well as~~and cylinder window glass.

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GLASS FOUND AT GLASTER BUT MADE ELSEWHERE

A small proportion of the glass assemblage from Glaster almost certainly did not originate at the glasshouse. These include a single clear and unweathered fragment of window glass, which is late 20th century in date. There are also two dark glass fragments probably made in a HLLA glass, one of which is identifiable as a wine bottle neck. Although they may well be 17th century in date, it is likely that these were vessels brought onto the site by the glassmakers, as was the case at Shinrone.

DIFFERENCES IN THE COMPOSITION OF ENGLISH AND IRISH HLLA GLASS

The Irish glass produced at Shinrone and Glaster is broadly similar to the HLLA glass produced in England in the late 16th- and early 17th-century (the average compositions for each group is set out in Table 9, Appendix 3). This suggests that similar furnace conditions and raw materials were used, which might be expected given that these furnaces share an association with glassmaking families of French descent. However, the Irish glass can be differentiated from the English equivalents because it contains lower concentrations of phosphorus (<1.8wt% P_2O_5) and manganese (<0.31wt% MnO) (Fig. 20). It is unlikely that the differences are due to the treatment of the plant ash, such as leaching with water, since the glass compositions each contain both soluble (e.g. potash) and insoluble (e.g. lime) components from the ash. Sanderson and Hunter demonstrated that it would be difficult to distinguish between the ashes of species such as oak and beech because of the similarities between the results, taking into account the large variability in ash composition for each species.[lxxx] However, they found that the manganese values for the ash from both species was strongly correlated with those of plants from each of the sites included in their study (data for phosphorus were not provided). Therefore, the low manganese and probably the phosphorus values for the Glaster and Shinrone glass may be predominantly attributable to the geology of the region where the plants for ashing were grown, in both cases Carboniferous Limestone, rather than the species of ash used.[lxxxi]

POSSIBLE RAW MATERIALS, AND THEIR PROPORTIONS, USED FOR GLASS PRODUCTION AT SHINRONE AND GLASTER

Potash and HLLA glasses were produced using ashes from plants, which can vary greatly in their composition. Accounts for the early 17th-century glasshouse at Ballynagerah, in Co. Waterford, list ashes from the tanyard and castle grates together with ash from kelp, fern and other unspecified types.[lxxxii] The ashes were combined with silica probably derived from sand, although quartz pebbles were also a potential source. Another contemporary record states that sand for glassmaking in Irish glasshouses came from England and that alkali was obtained locally from ash trees.[lxxxiii] Glass workers are often assumed to have collected waste glass, known as cullet, to add to their glass batches, although it seems more likely that glass produced at the furnace would have been recycled as cullet. Other factors, such as the temperature and duration of firing, and any additional stages involved in raw material preparation and glass production, such as fritting and refining, may also have affected the composition of the glass produced. In light of all of these variables, it is significant that the analytical results indicate that the glass produced at Shinrone had a consistent composition and the same is true of the glass produced at Glaster (Table 9, Appendix 3).

The consistency of the glass composition indicates that the furnace conditions were accurately controlled, that great care was taken over the selection and preparation of the raw materials and cullet, and that an ample supply of the same raw materials was probably available throughout the glassmaking period at Shinrone. It is known that Abraham Bigo's glasshouse lease included the condition that all of the wood for his glasshouse should be bought from the lessor, Parsons of Birr Castle.[lxxxiv] Therefore, it is likely that the Shinrone and Glaster furnaces each had relatively plentiful supplies of wood for ashing, and that in both cases the wood for ashing was obtained predominantly from a single source.

The woodlands in Offaly were mainly of oak, as described above, although Clonliske Wood in the Shinrone area consisted of both oak and ash. Analytical data are available for oak ash, where Turner indicates that the ash composition is approximately three quarters by weight lime, with the remainder made up of the oxides of potassium, phosphorus, magnesium and sodium.[lxxxv] Although this data does not include manganese, the results of Sanderson and Hunter indicate that several weight percent of manganese can also be present.[lxxxvi] The ratios of elements present in the oak ash are approximately comparable to those in the Shinrone glass, and therefore locally-grown oak is likely to have been the predominant source of ash used at Shinrone. However, the compositions of other types of wood ash, including birch and poplar would probably be similar to oak (providing that the plants grew in the same geological environment),[lxxxvii] and cannot be discounted. Beech ash is also similar but beech is not a native species in Ireland; it was introduced into the country on a small scale at the end of the 17th century, only becoming widespread in the 19th century.[lxxxviii] It is possible that small amounts of other types of ash may have been used as well, for example adding alkali-rich kelp ash would increase the proportion of soda present slightly.

The proportions of raw materials used to produce the Shinrone glass, calculated using the normalised and oxidised composition of ash, would be about 35wt% ash to 65wt% sand. However, in its original form, a large proportion of the ash would have been in the form of carbonates and compounds containing absorbed water rather than oxides.[lxxxix] The compositional data of Sanderson and Hunter suggest that less than half of the ash contributes to the glass composition and the rest is lost, for example as water and carbon dioxide during heating. Taking this into account the proportions by weight actually used by the glassmakers could have been nearer to 1:1 ash and sand, or slightly more ash than sand.

ESTIMATING THE QUANTITIES OF RAW MATERIALS REQUIRED FOR GLASS PRODUCTION AT SHINRONE

In the following discussion, an attempt has been made to estimate the amount of wood required to supply sufficient ash for each firing at the Shinrone furnace. For this, comparisons with furnaces in England from the late 16th century onwards have been made, on the basis that similar French glass-working traditions were practiced in England at to the same time as those employed at Shinrone in the early 17th century. However the estimate is very approximate because of the great variability in the yield and composition of wood ash.

The Shinrone crucibles were approximately 0.4m wide at the base, the rim diameter was estimated at 0.5m, and the crucible thickness was about 25mm. At Kimmeridge the crucibles were of a roughly comparable size with a base diameter of 0.32-0.37m, a rim diameter varying from 0.4 to 0.43m, a height of about 0.47m and a thickness of about 30mm.[xc] Therefore, in the following calculations, the height of the Shinrone crucibles has also been estimated as about 0.47m, although it was not possible to reconstruct any of the Shinrone examples to their full height.

The Shinrone crucible was approximated to a cylinder with a diameter of 0.4m and, assuming that the crucibles were not filled to the brim, the volume of glass in each crucible produced from raw materials, was estimated as 0.05m^3. The density of the glass was estimated at about 2200kg/m^3,[xci] and therefore the mass of glass produced per crucible was estimated at 110kg. By comparing the composition of the

Shinrone glass with data for oak ash, it was estimated previously that 35wt% of the glass mass, 38.5kg, was derived from plant ashes. However, the weight of ash actually added would have been considerably more than this, because about half the weight of the ash would be lost on heating as water and carbon dioxide.[xcii] From the data of Sanderson and Hunter, it has been estimated that around 42wt% of the ash added contributes to the glass composition, and therefore the amount of ash required per crucible is ~ 38.5 / 0.42 = 92kg.[xciii]

Of the wood burned, only 0.5wt% ash is produced for oak, according to Turner, therefore the amount of wood burned for ash per crucible would be 92 / 0.005 = 18.3 tonnes.[xciv] As four crucibles were used at Shinrone, this equates to about 70 tonnes of wood per firing, excluding the fuel for the furnace.

Although very approximate, this estimate indicates the vast quantity of wood required simply for ashing in order to produce four crucibles of glass. Wood was also required to fuel the furnace, but it is unclear how much of the ash from the fuel was recovered for use in the glass batch. The ash from the fire trench would be chemically changed by the high furnace temperatures since much of the potassium, an essential flux for the glass, would be lost as vapour, and this would make any ash recovered from the furnace less suitable for glassmaking.[xcv] Ash was also sometimes sourced already prepared. However, the large estimate above suggests that the deciding factor in the amount of wood consumed for glassmaking may have been the quantity of ash required for the batch rather than the fuel demands of the furnace.

CRUCIBLES

A total of 321 crucible sherds, weighing 30.795kg were recovered from the excavation at Shinrone. A quarter of the sherds (25.8%) were from the top soil and a large portion (22.7%) were from pit C57 which pre-dates the upstanding furnace. The next largest concentration (16.8%) was from C29, a layer up to ~~20cm~~ 0.2m deep directly beneath the sod, which extends west of the furnace and represents debris from the final phase of production. The remaining sherds were distributed over 30 contexts, with between ~~1~~ one and ~~13~~ thirteen sherds per context. The vast majority of fragments were body sherds, though some of the thicker sherds are more likely to have been from the bases, of which there are ~~4~~ four definite and 27 possible examples. The sherds vary greatly in thickness, from 14.6mm, presumably close to the rim, to 64.7mm, presumably at the base, with an average width of 30mm. Only ~~9~~ nine rims were identified, ~~7~~ seven of which have a rounded or slightly rounded profile, varying in thickness from 11.9mm to 23.6mm, and 2 broader flat rims, 26.2mm and 26.7mm thick, suggesting that two different types of crucible w~~h~~ere being used (Fig. 19).

It can be estimated, based on the curvature of some of the body sherds and the diameter of the basal impression on the siege platform~~,~~ that some, if not all, of the crucibles were of the ‘bucket’ type. ~~This is they~~These were *c*. 0.4m in diameter at the base, ~~with~~ the sides flaring outward slightly to *c*. 0.5-0.6m in diameter at the top. The corrosive effect of the glass batch on the crucibles is very clear on some of the sherds. Some 7% have evidence of scored runnels on the external surface and there is some evidence (1.5%) of internal horizontal grooves caused by the scum, or gall, that accumulated on the surface of the batch, as noted on crucibles from other excavations.[xcvi] While almost half of the sherds have a cream-green glaze both on the internal and external surface, the remainder, where a ‘glaze’ survives, have colourful vertical streaks incorporating white, mauve, light brown and olive green. Approximately 14% of sherds have waste material adhering to them and in some cases the fabric, usually grey in colour, appears to have been burnt. It would seem that these were crucibles that had fractured during the glassmaking process.

A number of crucible samples had microstructures indicative of very high temperatures, where a large proportion was heavily vitrified despite the refractory properties of the material. Analysis showed that the crucible clay comprised about 20wt% alumina~~,~~ and 70wt% silica ~~and~~ with small amounts of titania, potash and iron oxide. The same type of clay appears to have been used for the crucibles at Glaster, although more samples from Glaster are required to confirm this. The high ratio of titania to iron in this refractory clay is similar to that found in crucibles from English glasshouses of the late 16th century and 17th centuries in the Weald and ~~from~~ at Kimmeridge.[xcvii] These crucibles contained 78wt% silica, 20wt% alumina, 1.5wt% potash and 2wt% titania, which is consistent with the composition of a ~~a~~ pipe clay (ball clay).[xcviii] These white firing clays were obtained from Purbeck, Dorset, and from North and South Devon, and were used for pipe manufacture from the last quarter of the 16th century. This clay was also described by Merrett in 1662.[xcix] Other potential sources of crucible clay are mentioned in historical records, for example an early 17th-century manuscript for an unlocated glasshouse at ‘Ballynegery’, Co.

Waterford, states that ‘fine white or sky colour clay’ for the glass pots was obtained ‘from Fethard’, ~~probably in Co. Tipperary~~which could refer to a Fethard in Co. Tipperary or one in Co. Wexford.[c] Another record at about the same time, relating to the glasshouse at Clonbrone, states that the clay for the crucibles ‘came from the north’,[ci] while in 1633 the *Strafford Letters* list goods imported to Ireland from Malaga in Spain which includes ‘clay to make glass’.[cii]

The clay used for the production of the Shinrone and Glaster crucibles, the latter based on a single sample, had been tempered with rounded quartz grains, and also contained particles of grog. Analysis of the grog particles in each case indicated that these were made from the same type of refractory clay as the rest of the crucible. The addition of quartz and grog temper would have beneficially modified the properties of the clay~~ in several beneficial ways~~ by ~~. It would have ~~improv~~ed~~ing the green strength of the wet clay, making it easier for these large vessels to retain their shape until dry. This is important as during the drying process the lubricating water that gives the clay plasticity is lost, and is accompanied by shrinkage. The presence of temper, which has no drying shrinkage, facilitates even drying and reduces the overall shrinkage and warping of the clay.[ciii]

Given the similarity of the Shinrone crucibles to those used by Abraham Bigo at Kimmeridge, with ~~estimated ~~similar estimated refractory ranges, they would probably have started to lose their strength and shape at about 1550-1600°C and are likely to have experienced temperatures of between 1300-1350°C during use.

POTTERY

By Rosanne Meenan

As it is known that the glasshouse was in existence during the first half of the 17th century, the pottery from this site was of potential interest in relation to dating (Table 7). The sherds were very fragmentary, however, and it was difficult to recognise vessel forms. None of the pottery could be independently dated specifically to the first half of the 17th century. The very small number of sherds that came from contexts associated with the furnace could not be positively identified as 17th century in date, thereby raising the possibility that they were intrusive in those contexts. The sherds dateable to the later 17th century came from contexts that post-dated the upstanding furnace contexts.

The pottery assemblage appears to post-date the glasshouse and might more readily be associated with the occupation of the near-by, now demolished, country house. Agricultural activity associated with the house would, no doubt, have involved the manuring of fields from a dungstead located in the farmyard where pottery, discarded from the household, would have been mixed through the dung. If this is the means by which the pottery came to be deposited in the field around the furnace, the date range of the sherds suggests that the practise was carried out over a period of probably 200 years. Spreading over the surface of the fields might also explain the fragmentary nature of the sherds.

The range of wares present is not unusual. The presence of black-glazed storage vessels suggests that food processing and/or storage was being carried out while the range of drinking vessels and mass-produced table wares is also typical of the pottery found in Irish houses in the 18th century and particularly in the 19th century[civ]. It was not possible to discern the range of vessels in glazed red earthenware as the sherds were too fragmentary.

DISCUSSION

The barrel-vaulted furnace at Shinrone is typical of that of a ‘forest’ glasshouse. It had a rectangular ground plan with two parallel siege platforms and a fire trench between them, upon which stood four open-mouthed crucibles, two to each siege. The glass furnace would have been contained within an open-sided building measuring approximately 16m north-south by 10m east-west, possibly with a slate roof. A forest glasshouse at Woodchester, Gloucestershire, dating from 1590-1615 AD, was situated within an enclosure 15m square with a wall on one side and covered by a lean-to shed.[cv] This roofing arrangement may have been similar to that erected at Shinrone, where only one sidewall was uncovered. A similarly sized glasshouse, built in 1621, at Ballynegery, Co. Waterford was enclosed by a building described as consisting of ‘timber frame, boarding, doors, ladders and stairs and shindling [shingling]’ and measuring ‘forty or forty two feet square (approx. 12.5m sq) every way and thirty-six feet high (approx. 11m)’.[cvi] The glasshouse building at Kimmeridge Bay measured externally 12.5m x 11.5m with walls measuring 0.6-0.8m thick which may have supported a timber-framed structure.[cvii]

The large assemblage of glassworking waste from Shinrone is extremely important, not only in helping to identify the output of the furnace, but also in providing an understanding of the working practices that took place there. It is clear that, not unsurprisingly, only a HLLA glass was produced, and this ~~metal ~~is typical of broader glass production from the first half of the 17th century. Whilst much of the material, taking the form of lumps and partially processed glass, is relatively uninformative diagnostically, the assemblage also contains a very significant quantity of working waste. The hot-worked blowing waste is perhaps the most interesting, comprising almost entirely of moils and over blows from both window and vessel manufacture. Most unusually, the moils demonstrate~~d~~ that two specific sizes of blowing iron were being used, the first time this has ever been demonstrated on a glassworking site ~~from ~~of this period. The cold~~-~~working waste includes many off-cuts from cylinder glass production, although there is no evidence that quarries were actually cut and shaped there. ~~The f~~Fragments from finished items made at the furnace were also found. Inevitably, the majority of these are fragments of window glass prepared from blown cylinders and there is no evidence amongst the finished products or the working waste that crown glass was made. Although relatively scarce, fragments and wasters of vessel glass were also found. Interestingly, the most numerous vessel type that could be positively identified were small jugs or cruets, although this is probably biased by the survival of ~~ir ~~more di~~stinctive~~agnostic ~~surviving ~~elements such as handles and spouts. It is also clear that small containers were another staple product.

One area of site interpretation that the analysis of the glass can contribute to is the dating of the furnace. Whilst the window glass is fairly undiagnostic, and in isolation can only be dated broadly to the late 16th or 17th centuries, the vessel glass is more diagnostic. The small jugs are a relatively uncommon form, belonging to the first half of the 17th century, and a similar date is usually given to the small containers. However, more specifically, small cylindrical and square section bottles, such as those from Shinrone, are more usually found during the 1620s-50s, after which they appear to be superseded by more specialist phials. The other vessel fragments of interest are the early shaft and globe wine bottles. No example of this form has been found that can be positively dated any earlier than 1650, and the

Formatted: Indent: First line: 1.27 cm earliest realistic date range for these fragments ~~could belong to would be~~is 1650-60. ~~Given this~~Therefore, the vessel glass would indicate a period of operation for the furnace ~~to~~ between *c*.1620-60, ~~one that~~which is very close to that of the archaeomagnetic date of last firing, ~~to~~ 1620-50 (Appendix 2).

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It has already been noted ~~above~~ that there ~~is~~ was a strong connection between the Bigos and Henzeys operating in ~~Co.~~ Offaly and the activities, either of themselves or other family members, in England. A stronger ~~connexion~~ connection between the two sites, ~~(Kimmeridge and~~ Shinrone and Kimmerage,~~)~~ can be seen in the glass assemblages recovered. Unfortunately, the working waste from Kimmeridge was not examined in the published report, and the vessel glass only received cursory attention.[cviii] However, there are interesting comparisons that can ~~still~~ be made. Although no small spouted jugs were identified in the Kimmeridge report, there wa~~i~~s clearly a distorted spout ~~from one~~ present.[cix] Furthermore, small containers ~~are~~ were very common and there ~~are~~ were fragments from both cylindrical and square section bottles that are virtually indistinguishable from those found at Shinrone.[cx] Perhaps the most interesting vessels found at Kimmeridge ~~are~~ were reported as '~~"~~fragments (not drawn) apparently of bottles up to 9mm in thickness and approximately 130mm in diameter'~~"~~.[cxi] One such neck is illustrated (no 32), and this is very thick, wide and has an applied string course, which is unknown on flasks from the 1610-20s, and which, in any case, ~~are~~ were made in a much thinner glass. ~~Whilst~~ Although as yet there is no evidence that Bigo was the innovator of the wine bottle, it is clear he was experimenting in ~~producing~~ making larger bottle forms at Kimmeridge, even if not for commercial ~~sale~~production.~~, at Kimmeridge.~~ It is therefore, perhaps, not surprising that similar fragments ~~occur at an~~of an early date are also known from~~at~~ Shinrone ~~too~~. This is an extremely important finding as the origins of the wine bottle, which became the most common form of glass produced in England from the late 17th until the mid 19th century, are still not known.

~~*DIFFERENCES IN THE COMPOSITION OF ENGLISH AND IRISH HLLA GLASS*~~

~~The Irish glass produced at Shinrone and Glaster is broadly similar to the HLLA glass produced in England in the late 16th- and early 17th-century (the average compositions for each group is enumerated in Table 9, Appendix 3). This suggests~~

~~that similar furnace conditions and raw materials were used, which might be expected given that these furnaces share an association with glassmaking families of French descent. However, the Irish glass can be differentiated from the English equivalents because it contains lower concentrations of phosphorus (<1.8wt% P_2O_5) and manganese (<0.31wt% MnO) (Fig. 20). It is unlikely that the differences are due to treatment of the plant ash, such as leaching with water, since the glass compositions each contain both soluble (e.g. potash) and insoluble (e.g. lime) components from the ash. Sanderson and Hunter demonstrated that it would be difficult to distinguish between the ashes of species such as oak and beech because of the similarities between the results taking into account the large variability in ash composition for each species.[cxii] However they found that the manganese values for the ash from both species was strongly correlated with those of plants from each of the sites included in their study (data for phosphorus were not provided). Therefore the low manganese and probably the phosphorus values for the Glaster and Shinrone glass may be predominantly attributable to the geology of the region where the plants for ashing were grown, in both cases Carboniferous Limestone, rather than the species of ash used.[cxiii]~~

~~POSSIBLE RAW MATERIALS, AND THEIR PROPORTIONS, USED FOR GLASS PRODUCTION AT SHINRONE AND GLASTER~~

~~Potash and HLLA glasses were produced using ashes from plants, which can vary greatly in their composition. The early 17th-century glasshouse at Ballynagerah, in Co. Waterford, listed ashes from the tanyard and castle grates together with kelp and fern ashes, as well as other unspecified types, in their accounts.[cxiv] The ashes were combined with silica probably derived from sand, although quartz pebbles were another potential source. Another contemporary record states that sand for glassmaking in Irish glasshouses came from England and that alkali was obtained locally from the ash tree.[cxv] Glass workers are often assumed to have collected waste glass, known as cullet, to add to their glass batches, although it seems more likely that glass produced at the furnace would have been recycled as cullet. Other factors, such as the temperature and duration of firing, and any additional stages involved in raw material preparation and glass production, such as fritting and refining, may also have~~

~~affected the composition of the glass produced. In light of all of these variables, it is significant that the analytical results indicate that the glass produced at Shinrone had a consistent composition and the same is true of the glass produced at Glaster (Table 9, Appendix 3).~~

~~The consistency of the glass composition indicates that the furnace conditions were accurately controlled, that great care was taken over the selection and preparation of the raw materials and cullet, and that an ample supply of the same raw materials was probably available throughout the glass-working period at Shinrone. It is known that Abraham Bigo's glasshouse lease included the condition that all of the wood for his glasshouse should be bought from the leaser, Parsons of Birr Castle.[cxvi] Therefore it is likely that the Shinrone and Glaster furnaces each had relatively plentiful supplies of wood for ashing, and that in both cases the wood for ashing was obtained predominantly from a single source.~~

~~The woodlands in Co. Offaly were primarily of oak, as described above, although Clonliske Wood in the Shinrone area consisted of both oak and ash. Analytical data are available for oak ash, where Turner indicates that the ash composition is approximately three quarters by weight lime, with the remainder made up of the oxides of potassium, phosphorus, magnesium and sodium.[cxvii] Although this data does not include manganese, the results of Sanderson and Hunter indicate that several weight percent of manganese can also be present.[cxviii] The ratios of elements present in the oak ash are approximately comparable to those in the Shinrone glass, and therefore locally-grown oak is likely to have been the predominant source of ash used at Shinrone. However the compositions of other types of wood ash, including birch and poplar would probably be similar to oak (providing that the plants grew in the same geological environment),[cxix] and cannot be discounted. Beech ash is also similar but beech is not a native species in Ireland; it was introduced into the country on a small scale at the end of the 17th century, only becoming widespread in the 19th century.[cxx] It is possible that small amounts of other types of ash may have been used as well, for example adding alkali-rich kelp ash would increase the proportion of soda present slightly.~~

~~The proportions of raw materials used to produce the Shinrone glass, calculated using the normalised and oxidised composition of ash, would be about 35wt% ash to 65wt% sand. However, in its original form a large proportion of the ash would have been in the form of carbonates and compounds containing absorbed water~~

~~rather than oxides.[cxxi] The compositional data of Sanderson and Hunter suggest that less than half of the ash contributes to the glass composition and the rest is lost, for example as water and carbon dioxide during heating. Taking this into account the proportions by weight actually used by the glassmakers could have been nearer to 1:1 ash and sand, or slightly more ash than sand.~~

~~*ESTIMATING THE QUANTITIES OF RAW MATERIALS REQUIRED FOR GLASS PRODUCTION AT SHINRONE*~~

~~In the following discussion, an attempt has been made to estimate the amount of wood required to supply sufficient ash for each firing at the Shinrone furnace. For this, comparisons with furnaces in England from the late 16th century onwards have been made, on the basis that similar French glass-working traditions were practiced in England at to the same time as those employed at Shinrone in the early 17th century. However the estimate is very approximate because of the great variability in the yield and composition of wood ash.~~

~~The Shinrone crucibles were approximately 0.4m wide at the base, the rim diameter was estimated at 0.5m and the crucible thickness was about 25mm. At Kimmeridge the crucibles were of a roughly comparable size with a base diameter of 0.32-0.37m and a rim diameter varying from 0.4 to 0.43m.[cxxii] The crucible height was about 0.47m and their thickness about 30mm. Therefore in the following calculations, the height of the Shinrone crucibles has also been estimated as about 0.47m, although it was not possible to reconstruct any of the Shinrone crucibles to their full height.~~

~~The Shinrone crucible was approximated to a cylinder with a diameter of 0.4m and, assuming that the crucibles were not filled to the brim, the volume of glass in each crucible produced from raw materials, was estimated as 0.05m^3. The density of the glass was estimated at about 2200kg/m^3,[cxxiii] and therefore the mass of glass produced per crucible was estimated at 110kg. By comparing the composition of the Shinrone glass with data for oak ash, it was estimated previously that 35wt% of the glass mass was derived from plant ashes, 38.5kg. However the weight of ash actually added would have been considerably more than this, because about half the weight of the ash would be lost on heating, for example, as water and carbon dioxide.[cxxiv] From the data of Sanderson and Hunter (1981) it has been estimated that around 42wt% of~~

~~the ash added contributes to the glass composition, and therefore the amount of ash required per crucible is ~ 38.5 / 0.42 = 92kg.~~

~~Of the wood burned, only 0.5wt% ash is produced for oak, according to Turner (1956), therefore the amount of wood burned for ash per crucible would be 92 / 0.005 = 18.3 tonnes. As four crucibles were used at Shinrone, this equates to about 70 tonnes of wood per firing (not including the fuel for the furnace).~~

~~Although very approximate, this estimate illustrates the vast quantities of wood required simply for ashing in order to produce four crucibles of glass. Wood was also required to fuel the furnace but it is unclear how much of the ash from the fuel was recovered for use in the glass batch. The ash from the fire trench would be chemically changed by the high furnace temperatures since much of the potassium, an essential flux for the glass, would be lost as vapour, and this would make any ash recovered from the furnace less suitable for glassmaking.[cxxv] Ash was also sometimes sourced already prepared. However, the large estimate above suggests that the deciding factor in the amount of wood consumed for glassmaking may have been the quantity of ash required for the batch rather than the fuel demands of the furnace.~~

CONCLUSION

The Shinrone furnace is one of several glassmaking sites found in Offaly, all of which were established by Huguenot families in the 17th century (Fig. 1). It would appear that the principal reasons for the establishment of glasshouses in this county were the availability of land and a plentiful supply of timber. Other factors, such as the absence of silica for the glass and sandstone for the construction of the furnace itself, appear to have been less significant. Sandstone was chosen because of its high silica content which gives it excellent heat resistance. The sandstone for the furnace may have been sourced at either the Devilsbit Mountain, which lies 7km to the south-east, or the Slieve Bloom Mountains, which lie 12km to the east. There is also a known source of silica sand 27.6km to the east.

The Shinrone wood-fired glasshouse produced window and vessel glass of the high-lime, low-alkali (HLLA) type in the early 17th-century. The glass assemblage from the nearby furnace at Glaster, mainly consisting of working waste, was found to be similar to that from Shinrone. It was also of HLLA type, but with some subtle differences in composition. However, these differences are so small that they are most likely to be a result of the use of wood and sand from different, though geologically similar, locations. The glass from these two Irish sites could be distinguished from the HLLA glass made at English sites in the late 16th to early 17th centuries, by the low manganese and phosphorus content of the Irish material. This is due to the composition of the plant ash used and reflects predominantly the geology where the plants grew, and possibly the type of species used, at different furnace sites.

~~The furnace at Shinrone is an example of a typical forest glasshouse, barrel-vaulted, furnace. It had a rectangular ground plan with two parallel siege platforms and a fire trench between them, upon which stood four open mouthed crucibles, two on each siege. The glass furnace would have been contained within an open-sided building measuring approximately 16m north-south by 10m east-west, possibly with a slate roof. A forest glasshouse dating from 1590-1615 AD at Woodchester in Gloucestershire was situated within an enclosure 15m square with a wall on one side and covered by a lean-to shed.~~[cxxvi] ~~This roofing arrangement of resting on one sidewall may have been the type of roofing erected at Shinrone, where only one sidewall was uncovered. A similar sized glasshouse built in 1621 at Ballynegery, Co. Waterford was enclosed by a building described as consisting of 'the timber frame, boarding, doors, ladders and stairs and shindling' and measuring 'forty or forty two feet square (approx. 12.5m sq) every way and thirty-six feet high (approx. 11m)'.~~[cxxvii] ~~The glasshouse building at Kimmeridge Bay measured externally 12.5m x 11.5m with walls measuring 0.6-0.8m thick which may have supported a timber-framed structure.~~[cxxviii]

The upstanding furnace at Shinrone represents the final phase of glassmaking on site and was preceded by at least one earlier furnace, for which no *in situ* structural remains survive. At other wood-fired glasshouses it has been estimated that a furnace structure would survive ~~between~~ for two to three~~2-3~~ years and ~~would~~ then be replaced by a new structure. Merret, writing in 1662, ~~remarks~~ remarked that the crown of a green glass furnace 'rends in a quarter of a year, or else furrows will be made in them'.[cxxix] Evidence for this type of replacement can be seen at Shinrone and can be compared to a glasshouse at Knightons, Alfold, ~~in~~ Surrey, where a replacement furnace was built on the site of an earlier furnace.[cxxx]

~~Excavation of the medieval glasshouse at Blunden's wood, Surrey, revealed evidence of a screen wall located 2 feet to the north-west of the hearth of one furnace.~~[cxxxi] ~~A slot-trench for a similar screen wall may have existed at Shinrone, of~~

~~which only the foundation trench for a free-standing screen of wood or metal survived.~~

The presence of a pit filled with fragments of an earlier furnace, along with broken crucible sherds, can be compared to a similar pit uncovered during the excavations of an early 17th-century glass furnace at Jamestown, Virginia. This pit was located in front of the main furnace, measured 2.4m square and 0.5m deep, and contained the remains of furnace refuse, old crucibles, stone spalls, glass drippings and slag.[cxxxii] This pit was associated with a secondary phase of glassmaking at the site and was the result of the rebuilding of a glass furnace, which replaced an earlier furnace. A similar sequence appears to have occurred at Shinrone where the debris of an earlier furnace and waste crucibles were dumped into a pit to the west of the furnace that was sealed with a layer ~~which~~ that was contemporary with the upstanding furnace. Earlier glassmaking activity may have occurred upslope to the west of the upstanding furnace.~~, the latter representing the final phase of glassmaking activity at Shinrone.~~

A layer of coal cinders ~~were~~ was found at Shinrone suggesting the possibility that the glassmakers were experimenting with coal-fired technology. At a comparable rectangular forest glasshouse of 17th-century date in Sidney Wood, Alfold in Surrey a layer of coal cinders was similarly dis~~un~~covered.[cxxxiii] Layers of coal cinders were also ~~uncovered~~ uncovered at a late 16th-century furnace at Somersbury, Ewhurst, Surrey and at an early 17th-century furnace at Petworth Park, Lugershall, Sussex.[cxxxiv] All of this evidence suggests that forest glassmakers ~~appear to have been~~were experimenting with coal-fired technology in the early 17th century.

~~The Shinrone furnace is one of several glassmaking sites found throughout Co. Offaly all of which were established by the Huguenots in the 17th century (Fig. 1). It would appear that the primary attraction for constructing glasshouses in Co. Offaly was the availability of land and a plentiful supply of timber. Other factors, such as the absence of silica for the glass and sandstone for the construction of the furnace itself, were mitigated by the relatively close availability of these materials. The sandstone for the furnace was deliberately sourced at the Devilsbit Mountain and the Slieve Bloom Mountains, 7km and 12km to the south-east and east respectively as its high silica content gave it excellent temperature resistance. There is also a known source of silica sand 27.6km to the east.~~

~~The Shinrone wood-fired glasshouse produced window and vessel glass of the high-lime, low-alkali (HLLA) type in the early 17th-century. The glass assemblage from neighbouring Glaster, primarily consisting of working waste, was found to be similar to the glass at Shinrone. It was also of HLLA type, but with some subtle differences in composition. However, these differences are so small that they are most likely to be a result of the use of wood and sand from different locations (although geologically similar), perhaps near to each furnace and consequently with slightly different compositions. The glass from these two Irish sites could be distinguished from the HLLA glass made at English sites in the late 16th to early 17th centuries, by the low manganese and phosphorus content of the Irish material. This is due to the composition of the plant ash used and reflects predominantly the geology where the plants grew, and possibly the type of species used, at different furnace sites.~~

The consistency of the glass composition indicates that great care was taken in the selection of the raw materials and the control of the furnace operating parameters, and also that a plentiful supply of wood, from the same source, was probably available for ashing throughout the lifetime of the glasshouse. Contemporary sources of this period often refer to the dense woodlands of Ireland, which were ~~The density of woods,~~ predominantly ~~of~~ oak. ~~, at this period is often referred to in contemporary sources and it was seen as one of the advantages of glassmaking that these woods would be cut down and therefore prevented from becoming places of refuge for any rebellious native Irish. A~~ An estimated 70 tonnes of wood would have been required to provide the ash for each firing, given that there were four crucibles to be supplied. It is highly likely that the ash would have been retrieved from the burnt furnace fuel so it is difficult to estimate how much extra wood was required to fuel the furnace fire.

~~The furnace would have reached temperatures of at least 1260-1290°C in order for the glass to completely melt. Refractory materials were used to construct the furnace (sandstone and quartz-tempered brick) and for the crucibles (quartz and grog-tempered fire clay). The refractory clay is similar to the one utilised for crucibles at Kimmeridge by Abraham Bigo.~~

The furnace had a single flue suitable for use with wood billets, which produce a long flame. The narrowing of the flue towards one end may suggest some directionality in the way it was used. There was no chimney but there were five small vents in the furnace roof that would have facilitated control of the fuel burning rate, and hence the temperature, as well as allowing smoke to escape, thereby influencing the furnace atmosphere. ~~Potash-rich vapour, resulting from the disassociation of potassium carbonate in the fuel ash, reacted with the crucible surfaces and the interior walls of the furnace, causing the surfaces to glaze and ultimately resulting in droplets of transparent blue glaze falling from the furnace roof and walls; droplets of this 'kiln sweat' were found during the excavations.~~

The French families associated with the Shinrone and Glaster furnaces also ~~have~~ had links with glassmaking sites in England, such as at Kimmeridge, in Dorset, and in Staffordshire. Therefore there is potential to compare further, and in more detail, the technology and materials used at these, and other, glass furnace sites in late 16th and early 17th-century England. The excellent survival at Shinrone provides a unique opportunity to investigate the workings of post-medieval wood-fired glasshouses, which can be exploited in future research.

ACKNOWLEDGEMENTS

This research excavation was grant-assisted by funding from the National Monuments Service, ~~currently under the~~ Department of Arts, Heritage and the Gaeltacht, on the recommendation of the National Committee for Archaeology of the Royal Irish Academy. Many thanks to the following: the landowner, Éamon Cleary, for ~~all~~ his cooperation; Noel McMahon, who introduced us to the furnace; the late Mary Boydell, who did pioneering work on the glasshouses ~~in~~of ~~Co.~~ Offaly~~,~~ and for her support and the generous sharing of her work; Matt Phelps, for additional analysis of the glass; Catherine O'Brien, for the maps, plans and sections; Patsi Bates, for the illustrations of the crucible sherds and Jerneja Willmott, for the illustrations of the glass. Finally thanks are due to the site assistants Lucy Chapman, Pauline Gleeson, Mark Hart, James Lyttleton, Matthew Logue, Jo Moran, Noelle O'Looney, Daniela Wittorf; and to Barry O'Reilly and ~~to~~ Roger Hensey for ~~a final~~ proof-reading.

APPENDIX 1: THE MAGNETOMETER SURVEY

By Joe Fenwick

A magnetometer survey was conducted at the site in April 1999~~. The survey~~, using a Geoscan FM36 fluxgate gradiometer, ~~was confined to~~within a square area measuring 40m by 40m (0.16 ha~~ectares~~), aligned approximately to magnetic north. Within this area the ground slopes gently downhill from west to east at a gradient of approximately 1 in 20. The underlying bedrock geology is predominantly of carboniferous limestone with an overburden of glacial gravel and till. The upstanding remains of the stone-built barrel-vaulted furnace (a little to the southwest of centre of the surveyed area) and two mature sycamore trees (in the south-western quadrant) presented some minor physical obstruction to the survey (Fig. 21). The land, at the time of survey, was under pasture and appears not to have been cultivated in the recent past. Indeed, the excellent state of preservation of the furnace may suggest that the ground in this area has remained relatively undisturbed since the site was abandoned.

A total of ~~16~~ sixteen survey grids, each measuring 10m by 10m, were surveyed within the pre-defined survey area. Measurements of magnetic gradient were taken at 0.5m station intervals, in parallel-mode south to north, along parallel transects set 0.5m apart (i.e. 400 individual readings per survey panel). The composite image is therefore generated from almost 6,400 individual measurements of magnetic gradient: several null or 'dummy' values, however, were required where obstructions prevented readings being taken. Some simple processing procedures have been applied to the data including 'de-drifting' and 'edge-matching' of individual survey panels. No filters have been applied to the dataset and therefore figures 21 and 22 (grey-scale and wire-frame images) are representative of the range of values present in the raw dataset. Similar procedures were applied to the data presented in figure 3, but in this instance the data-range has been clipped to between plus and minus 10 nanoTesla (nT) in an attempt to isolate or enhance some of the lesser magnetic anomalies, some of which may be of archaeological significance. This range, though representing the statistical bulk of the dataset, proves to be rather noisy and unfortunately does little to resolve or clarify the overall picture.

Figure 23 displays an extraordinary wealth of distinct magnetic anomalies and other more diffuse magnetic zones, reflecting, as one would expect, the high-temperature processes required in the production of glass from its constituent raw materials and its subsequent moulding, blowing and shaping to form glass objects. Kilns furnaces and ovens, or other archaeological features subjected to intensive burning, will exhibit a strong permanent thermoremanent magnetism.[cxxxv] The extant furnace, lying a little to the southwest of centre of the image (G1), displays by far the strongest magnetic signature within the surveyed area. The distribution of other, more amorphous, magnetic anomalies surrounding the furnace do not display a clearly defined pattern but appear instead to be randomly dispersed over the survey area. There is no immediately obvious pattern in the geophysical imagery that can be interpreted, for instance, as the sub-surface remains of building foundations, although it is likely that such did exist in the vicinity of the extant furnace structure. It is probable, however, that the strength of the magnetic field emanating from the extant furnace, and from a number of other distinct sources within the survey area, may have simply overwhelmed the more ephemeral magnetic sources also present. Some archaeological features with relatively weak magnetic properties, therefore, may be hidden or obscured by those displaying stronger magnetic signatures. Those more distinct, visible, magnetic anomalies, however, are likely to reflect a number of possible archaeological sources.

Ferromagnetic objects, either ferrous litter (e.g. modern nails, horseshoes, barbed-wire, etc.) or iron will also display as strongly magnetic point-source anomalies. Discrete, very localised, dipolar magnetic sources are commonly due to the presence of near-surface iron objects. These characteristically display as sharp, point-source, magnetic 'spikes' in the dataset – a select number of which have been labelled G2 in figures 22 and 23.

Those more diffuse magnetically anomalous zones surrounding the extant furnace may also have an archaeological significance. The furnace superstructure and its sub-surface remains exhibit a very large magnetic presence over an extensive surrounding area. Other anomalous magnetic zones – if not due to a concentration of buried ferrous material – may possibly be a result of other, lesser, thermoremanent sources. These, for instance, may be the remains of buried sections of the partially destroyed furnace or other areas where intensive burning has occurred – perhaps an annealing furnace – or simply an area where the by-products of this industrial activity (ash, cinders, etc.) were deposited or buried in pits. Of potential interest in this regard are a number of anomalous zones to the east, south and southwest of the extant furnace (G3). These, in addition to the area in the immediate vicinity of the extant furnace, may warrant further investigation or excavation to ascertain the true nature of these magnetic sources.

APPENDIX 2: THE ARCHAEOMAGNETIC DATING

by William A McCann and Malcolm Gould

The Clark Laboratory
Museum of London Archaeology Service

Measurement Ref. CL-29/1
Feature: Burning associated with glasshouse furnace – context C14
Lat: 52.97°N; Long: 7.93°W
Orientation: Gyro theodolite
Sampling method: Discs
No. of samples used/taken: 17/30
Removal of viscous magnetisation: 30 mT AF peak field
Sampled 18/5/99. Final report 8/5/99.

Thirty samples were taken from an area of heated material found to the north of the glasshouse, thought to be the location of the furnace stoke hole, with the aim of determining the date of last firing.

At the time of sampling it was noticed that there were slight differences within this fired deposit, potentially representing different phases of heating activity, and so the sampling and analytical strategy reflected this possibility. Samples were loosely clustered into four groups across the feature and initial analysis was based upon these very low declination values in group 1 that exemplify this phenomenon. This movement can most likely be attributed to root action, sloping terrain, consolidation of made ground and/or modern disturbance.

~~The seventeen samples used for mean calculations were unaffected by subsidence. Evaluation found that any variation between the mean values from the four groups of samples were insignificant. The dates quoted below are thus applicable to the feature as a whole. The overall mean provided the most accurate results giving an alpha-95 measurement of 1.55°, a very satisfactory level of consistency and accuracy.~~

~~The mean direction of magnetic remanence after the last firing was: Declilnation = 5.068° W; Inclination = 72.472°; alpha-95 = 1.55°~~

~~This gives a date range of AD1620-1650 at the 68% confidence level and AD1610-1660 at the 95% confidence level.~~ If enough uniform samples permitted, a mean value for declination and inclination was calculated for each cluster; then comparisons drawn between groups and a mean of all samples.

The specimens were dried over a period of several days and then consolidated by slow impregnation with a solution of PVA in acetone. In the laboratory, the natural remnant magnetism was measured in a Molspin fluxgate spinner magnetometer. The resultant data were then adjusted to the local geomagnetic variation before mean values were created.

Three pilot samples were subjected to a staged demagnetisation process to remove any viscous magnetism present. However, demagnetisation did not result in an improvement of results and so was not applied to all samples. Therefore the date range presented below is that obtained pre-demagnetisation.

Results

The samples were in general found to be poorly magnetised with low intensity values (see Table 9, Appendix 3). For a deposit associated with a structure of such high temperatures, this was unexpected. This suggests that the deposit was not physically related to the primary heat source for the glasshouse. Magnetisation of the deposit may have occurred via an intensely heated surface overlying this deposit or could have come directly from a lesser heat source (possible 'rake out').

Samples taken from group 1, found closest to the glasshouse structure, were found to be most intensely magnetised. It was also noticeable that this area had undergone the least amount of movement or subsidence. This problem affected thirteen samples which were found to be no longer precisely in situ and so were unsuitable for the final stages of processing. The high declination values in group 3 and very low declination values in group 1 exemplify this phenomenon. This movement can most likely be attributed to root action, sloping terrain, consolidation of made ground and/or modern disturbance.

The seventeen samples used for mean calculations were unaffected by subsidence. Evaluation found that any variation between the mean values from the four groups of samples were insignificant. The dates quoted below are thus applicable to the feature as a whole. The overall mean provided the most accurate results giving an alpha-95 measurement of 1.55°, a very satisfactory level of consistency and accuracy.

The mean direction of magnetic remenence after the last firing was: Declination = 5.068° W; Inclination = 72.472°; alpha-95 = 1.55°. This gives a date range of AD1620-1650 at the 68% confidence level and AD1610-1660 at the 95% confidence level.

APPENDIX 3: ANALYTICAL METHODOLOGY

~~Twenty-one~~Some 21 or more examples, including pale green window glass (one with iridescent weathered surfaces), vessel glass, lumps and dribbles of glass, bottle glass and droplets of transparent blue glass were sampled for examination and analysis using a scanning electron microscope with an energy dispersive spectrometer (SEM-EDS).[cxxxvi] The conditions used for analysis were an accelerating potential of 25kV, a beam current of 1.5nA and a counting time of 150s. Standard glasses of known composition were also analysed using SEM-EDS. On the basis of the analytical results for glass standard D, the most similar to the glasses discussed in this report, an SEM-EDS analysis would be anticipated to be within about 20% relative of the Na_2O content, 5% of the MgO and Al_2O_3 content, 2% of the SiO_2, K_2O and CaO content, 12% of the P_2O_5 and MnO content and 18% of the Fe_2O_3 content. The detection limits for most elements measured by SEM-EDS were 0.1wt%, but 0.2wt% for P_2O_5 and SO_3 and 0.3wt% for Na_2O, BaO, SnO_2 and Sb_2O_5 (Table 9).

Additional analysis was carried out for three selected elements (manganese, zinc and strontium) using X-ray fluorescence spectroscopy (XRF) due to its superior detection limits over the SEM. These elements had shown up as minor and trace amounts in the SEM analysis and strontium is particularly interesting as it can indicate the use of seaweed ash. The XRF was an Eagle II, set to 40kV accelerating potential and 1000µA current. Calibration was carried out with a range of suitable standards and comparative material (Corning A, B and C; Nist 1834; Shaw House 100, 106 and 107; LOP 06 and 57). Detection limits indicated by the graphs were 0.02% for all three elements.

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'Will of Philipp Bygoe of Newtown, 1664', National Archives of Ireland, Prerogative Will Book/F/186a.

Abbreviations

HLLA High lime low alkali

HMSO Her Majesty's Stationery Office

SMR Sites and Monuments Record

The site archive, including the finds, is currently in the care of the excavators.

[i] The glass furnace was brought to the excavators attention by Noel McMahon.

Formatted: English (Ireland)

[ii] Farrelly 2003, 268.

[iii] www.offaly.ie/eng/Services/Heritage/Digital_Media/Archaeology_3d/Download_3d_scans_of_Offaly's_carved_stone_and_structures.html

[iv] SMR number OF042-049----. ITM 604110 690396.

[v] Nuttal-Smith 1923, 22.

[vi] Down Survey map of Kilcomin Parish, 1654-56.

[vii] Nuttal-Smith 1923, 127.

[viii] Farrelly 2010, 50-51.

[ix] Grayson 1998.

[x] Henderson and Ivens 1992, 52-64.

[xi] For a discussion of early 17th glassmaking in Ireland see Farrelly 2010, 33-54.

[xii] Hamilton 1890, 466.

[xiii] Tyzack 1997, 15-16.

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[xiv] See appendix 2.

[xv] Tyzack 1997, 15-16.

[xvi] Down Survey map of Kilcomin Parish, 1654-56.

[xvii] Pender 1939, 441.

[xviii] Ellis 2002, 126.

[xix] Pender 1939, 443.

[xx] Pender 1939, 443.

[xxi] Ellis 2002, 124; Guttery 1956, 30.

[xxii] The Books of Survey and Distribution record that Joshua was granted land at 'Curragh Ureanry Milltown, Garvally', near Banagher.

[xxiii] The Books of Survey and Distribution record that Thomas was granted land at Aghancon and Ballybrack (the latter is 4km south-east of Shinrone glasshouse).

[xxiv] Guttery 1956, 30-31.

[xxv] Prerogative Will Book/F/186a.

[xxvi] SMR number OF034-009----. ITM 652800 711661.

[xxvii] Mahaffy 1910, 301-02.

[xxviii] Mahaffy 1910, 301-02.

[xxix] Westropp 1978, 32-6.

[xxx] Watts 1996, 3.

[xxxi] Ellis 2002, 125-6.

[xxxii] Crossley 1987, 343-8.

[xxxiii] Godfrey 1975, 120-1.

[xxxiv] SMR number OF035-030----. Precise location unknown.

[xxxv] Fenlon 1998, 18.

[xxxvi] Westropp 1978, 31.

[xxxvii] Hogan 1980, 42.

[xxxviii] Loeber 1998, 287-318.

[xxxix] Add. Ms. 4756 f.125, MILLES COLLECTION.

[xl] Farrelly 2010, 42.

[xli] Cooke 1875, 41-2.

[xlii] Fenlon 1998, 17; for a discussion on the market for window glass in Ireland at this period see Roche 2010, 55-82.
[xliii] Fenlon 2003, 21-2.
[xliv] Mss. A/8 Birr Castle Archives.
[xlv] Cooke 1875, 42-3.
[xlvi] Fenlon 1998, 18.
[xlvii] Shaw, W. A. 1911, 336. Letters of Denization and Acts of Naturalization for Aliens in England and Ireland, 1603-1700.
[xlviii] Boate 1652, 162.
[xlix] Feddaun Castle, also known as Newtown Castle SMR No. OF029-013----, is located in the townland of Ballynasrah.
[l] The Books of Survey and Distribution record that 'Phillip Bigoe' owned 90 acres of land in 'Killonrny' [Killowney], which is between Banagher and Cloghan, 12 acres of land in 'Garcora' and land in 'Newtown & part Corat [Corator], Balliliry' in Lusmagh parish.
[li] Pender 1939, 443; T.C.D. manuscript F.27 - 1646, 87a-89.
[lii] Mary Boydell pers. comm.
[liii] SMR number OF029-024----. ITM 601247 709997.
[liv] 1641 Depostitions: Deposition of Phillip Bygoe, TCD Ms. 830, fols 132r-133v.
[lv] Symner, Notes on Ireland's Natural History, TCD Ms. 5926
[lvi] SMR number OF024-074----. ITM 625988 721708.
[lvii] Simington 1961, 30.
[lviii] Crossley 1967, 59.
[lix] Crossley 1990, 272.
[lx] Misra *et al*., 1993.
[lxi] Briggs, 1987, 372.
[lxii] Pape 1933-4, 102.
[lxiii] Wood 1965, 56.
[lxiv] O'Brien *et al*. 2005; Phelps 2010.
[lxv] Willmott 2009.
[lxvi] See Willmott 2005, Chapter 4.
[lxvii] Tyler and Willmott 2005, 48.
[lxviii] Willmott 2005, 101.
[lxix] Willmott 2005, 12-3.
[lxx] Diderot depicts blowing irons associated with crown glass manufacture that have both bulbous and everted tips, although it is uncertain whether there was a functional difference between them; Gillispie 1959, Plate 237.
[lxxi] Crossley 1987, 377.
[lxxii] Willmott 2005, 12-3.
[lxxiii] Traditionally this measurement is undertaken manually by placing each fragment on a piece of graph paper, but given the quantity of window glass present this was not practicable, and instead a computer scanner programme was used; Leaf Area Measurement version 1.3 (© 2003 University of Sheffield).
[lxxiv] Crossley 1987, 362 no 103.
[lxxv] Willmott 2002, 77.
[lxxvi] Willmott 2002, 86-9.
[lxxvii] Phelps 2010, 8.
[lxxviii] Egan 1999, 67.
[lxxix] For an early discussion of this transition to kelp glass see Parkes 1823.

[lxxx] Sanderson & Hunter 1981.
[lxxxi] Hallissy 1979.
[lxxxii] Ms. Z3.1.3 (12), Marsh's Library.
[lxxxiii] Boate 1652, 162.
[lxxxiv] Westrop 1978, 31.
[lxxxv] Turner 1956; Sanderson & Hunter 1981.
[lxxxvi] These data are only used as a guide to the contribution of the ash to the glass, because of the compositional variability of ash and also because not all of the elements in the ash are in a form that can be easily incorporated into the glass (Turner 1956). For example, the reaction of the chlorides, NaCl and KCl, and sulphates with the glass batch is limited, and both are poorly soluble in molten glass.
[lxxxvii] Turner 1956; Sanderson & Hunter 1981; Stern & Gerber 2004.
[lxxxviii] McCracken 1971, 39, 135.
[lxxxix] Stern & Gerber 2004.
[xc] Crossley 1987, 369-70.
[xci] Mazurin *et al.* 1987.
[xcii] Stern & Gerber 2004; Misra *et al*. 1993.
[xciii] Sanderson & Hunter 1981.
[xciv] Turner 1952.
[xcv] Paynter 2008.
[xcvi] Such as at Vauxhall see Tyler and Willmott 2005, 45-6.
[xcvii] Briggs 1987, 372; Paynter forthcoming.
[xcviii] Holdridge 1956.
[xcix] Cable 2001, 299.
[c] Ms. Z3.1.3 (12), Marsh's Library.
[ci] Boate 1652, 162.
[cii] Knowler 1740, 104.
[ciii] Hamer & Hamer 1997; Kingery & Vandiver 1986.
[civ] Orser 2010, 89-99
[cv] See Baddeley 1920, whose original ground plan showing post settings for a roof structure is much clearer and more accurate than the one reproduced from Daniels 1950 in most secondary works.
[cvi] Westropp 1978 30.
[cvii] Crossley 1987, 354.
[cviii] Crossley 1987, 355-62.
[cix] Crossley 1987, 362 no 103.
[cx] Crossley 1987, 358.
[cxi] Crossley 1987, 359-60.
[cxii] Sanderson & Hunter 1981.
[cxiii] Hallissy 1979.
[cxiv] Ms. Z3.1.3 (12), Marsh's Library.
[cxv] Boate 1652, 162.
[cxvi] Westrop 1978, 31.
[cxvii] Turner 1956; Sanderson & Hunter 1981.
[cxviii] These data are only used as a guide to the contribution of the ash to the glass, because of the compositional variability of ash and also because not all of the elements in the ash are in a form that can be easily incorporated into the glass (Turner 1956). For example, the reaction of the chlorides, NaCl and KCl, and sulphates with the glass batch is limited, and both are poorly soluble in molten glass.

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[cxix] Turner 1956; Sanderson & Hunter 1981; Stern & Gerber 2004.
[cxx] McCracken 1971, 39, 135.
[cxxi] Stern & Gerber 2004.
[cxxii] Crossley 1987, 369-70.
[cxxiii] Mazurin *et al.* 1987.
[cxxiv] Stern & Gerber 2004; Misra *et al*. 1993.
[cxxv] Paynter 2008.
[cxxvi] See Baddeley 1920, whose original ground plan showing post settings for a roof structure is much clearer and more accurate than the one reproduced from Daniels 1950 in most secondary works.
[cxxvii] Westropp 1978 30.
[cxxviii] Crossley 1987, 354.
[cxxix] Cable 2001, 299.
[cxxx] Wood 1982.
[cxxxi] Wood 1965, 56.
[cxxxii] Harrington 1952, 17.
[cxxxiii] Kenyon 1967, 205.
[cxxxiv] Kenyon 1967, 202, 207.
[cxxxv] Clark 1996; Gaffney & Gater 2003.
[cxxxvi] For a full summary see Paynter in O'Brien *et al.* 2005.