A WINDOW ONTO THE MEDIEVAL WORLD

The Consumption of English Window Glass at High Status Monastic Sites in England, 12th to 16th Century

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For my father
Peter William Stone

Abstract

The purpose of the study was to examine the consumption of English window glass at high status sites, using a case study of excavated window glass dated from the 12th to 16th centuries from selected Benedictine and Cistercian abbeys across England. Glassmaking in England appears to have only started in the 13th century and at this point was a nascent industry, in competition with window glass procured from the continent. Seven monastic sites were selected across complementary sites spanning the length of England, and 284 samples of excavated window glass were examined, using stylistic, technological, art historical and chemical techniques.

The thesis shows all the window glasses in the study were sourced from France, Germany and England. French window glass dominated all monastic establishments until the mid-14th century, after which time German glass dominates. English window glass appears to have been used in the first half of the 14th century and onwards; however, evidence for its use is scarce, and those abbeys in closer proximity to the major glassmaking areas in the Weald and Staffordshire appear to have been the early adopters. Moreover, abbeys in the east favoured German and some English glass, while those in the west bought their glass from France. English producers limited their market appeal because of their failure to produce coloured glass (whether through choice or a lack of knowledge), while the continental producers could supply both coloured and uncoloured. This resulted in a more restricted range of decorative elements applied to the English glasses.

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Glossary

Glassmaking

Annealing	Slow cooling of finished glass to prevent the build-up of internal stresses
Lehr or leer	Annealing oven
Batch	Mixture of raw ingredients
Seeds	Small bubbles
Inclusions	Unmelted particles
Fining	Removing bubbles by raising the temperature of the melt
Contamination	Glass may have reacted with eg waste in bottom of crucible, wood ash in furnace
Parison	Gather of partly inflated glass, from French 'paraison'
Siege	Bench inside furnace which crucibles sit on
Gaffer	The master glassmaker
Boy	Person who takes the made objects to and from lehr
The stoker	The person who maintains the furnace fire
Cullet	Originally glass left on the blowing iron after vessel removed, from French 'collet' (collar). Also scrap/broken glass
Marver	Hard, flat surface to roll and shape glass, from French 'marbre'
Flux	From French for flowing
Pontil/puntee	Iron rod tipped with molten glass for handling vessel e.g. cylinder during manufacture
Blowing iron	Iron or steel pipe for blowing glass parison
Furnace	From French 'fornais', C13
Pincers	Tool for gripping hot glass objects, from French 'pinceour'
Moil	A ring of glass left on the end of the blow pipe after the cylinder or crown has been detached

Glass painting and window production

Cut line	Outline drawing showing lines where to cut glass and for leading
Grozing	Trimming / 'nibbling' glass to shape with grozing iron - a hooked tool.
Vidimus	Preparatory sketch for window; 'we have seen'
Cartoon	Original sketch of window design
Quarry	Pieces of glass cut into regular geometric shapes
Breaking / cutting	eg of quarries, instead of, or in addition to grozing
Durability	Susceptibility to corrosion and decay
Came	Lead strip with an H-shaped profile to hold glass quarries in place
Lead shadows	Dark or white lines left on glass after removal of lead
In reserve	Area around the pattern is painted, the pattern itself is left unpainted
Stickwork	Pattern is picked out / scratched from a matt wash of paint
Stipple shading	Shading (to appear three-dimensional) by dabbing paint on with a brush
TPQ	Terminus post quem: the earliest date
TAQ	Terminus ante quem: the latest date

Chapter 1

1. Introduction

There is no evidence for the production of glass from the primary raw materials in England until the 13th century, when written records and archaeological evidence show that a fledgling glassmaking industry was operating in the Weald on the Surrey-Sussex border and in Staffordshire (Kenyon, 1967, p. 26; Welch, 1997, p. 16). Prior to this period, glass had been imported. In the first millennium primary glass made by Roman glassmakers was imported, re-melted, and reworked, mostly into vessels at secondary workshops in England, for example at Leicester in the 3rd century AD (Willmott, 2005, pp. 21–24; Freestone and Stapleton, 2015, p. 64; Jackson and Paynter, 2021, p. 254). In the Anglo-Saxon period secondary glasshouses in England re-melted and reworked imported glass to make window glass for high status religious buildings, such as Jarrow Monastery and St Peter's church in York in the 7th century (Cramp, 2005; Freestone, 2006; Willmott, 2005, p. 33). Around the 8th to the 10th century, window glass was made from the raw materials in the forests north of the Alps in continental Europe; this type of glass is sometimes called 'forest glass'.

Monastic expansion across Europe in the 11th century stimulated the glass industry in Germany, France, and central Europe all producing forest glass to provide the glazing for the new monasteries - including those in England. In the 1530s at the time of the Dissolution, there were nearly 900 monasteries in England (Knowles and Hadcock, 1971, p. 494). Initially, sheets of pre-formed window glass were imported from the continent; however, from the 13th century, English glass was used - for example at Westminster Abbey, the royal chapels at Windsor and Westminster, and York Minster, although evidence is scarce (Marks, 1993, p. 30; Adlington *et al.*, 2019). It is thought that the English glasshouses were established by immigrant glassmakers from the continent, particularly Normandy, as there are references in local deeds and manorial rolls to glassmakers of French origin (Winbolt, 1933, p. 7) and many of the names of the tools and processes used in glassmaking are French words: pontil, pincer, flux, cullet, siege and marver among others (see glossary).

Although forest glass was essentially a two-ingredient material - a source of silica, usually sand and a wood ash flux to reduce the melting temperature, it was difficult to make. So, despite its basic components, window glass was a high status material and used in palaces, cathedrals and abbeys. A few surviving literary sources written on the continent provide some of our understanding about glassmaking in the medieval period, the most well-known and informative of which is the 12th century *On Divers Art* by Theophilus. However, Theophilus and other authors, such as Biringuccio (1540), Agricola (1556) and Eraclius (12th or 13th century), were not glassmakers, and the assumptions about glassmaking processes derived from literary sources have been tested through experimental work. Scientific research has thrown light on,

for example, the identification of different raw materials and glassmaking technology. Documentary sources such as purchase records and manorial rolls have provided some details about where some of the window glass that was made in England was used (Ashdown, 1919, p. 26; Kenyon, 1967). A large corpus of medieval window glass is found in extant cathedrals and churches, although many of the windows have been rearranged and glasses of multiple dates have sometimes been consolidated into one window. Nonetheless, original, well-dated windows can be used for dating excavated fragments of window glass by matching the decoration. It is difficult to analyse and attempt provenance of this in-situ glass unless it is removed for restoration; the Great East Window (GEW) from York Minster is a rare example (Freestone *et al.*, 2010). Portable X-ray fluorescence (pXRF) analysis has been used on the GEW, although combining results with data from other analytical techniques to provenance the glass (Adlington, 2019), and pXRF has also been used to determine glass types and the broad dates of in-situ window glass at a number of sites, including Ightham Mote (Girbal and Dungworth, 2011).

Although evidence is rare, the archaeological excavation of furnace sites in Europe has revealed some details about the furnace design and operation. The working waste, cullet (broken glass for remelting), and wasters retrieved from these sites have been chemically analysed to determine their composition. This data has been made available for use in studies assigning a broad provenance to window glass retrieved from consumption sites, although the data set is small (for example, Wedepohl, 1996; Mortimer, 1997; Cílová and Woitsch, 2012). Abbeys were consumers of vast amounts of window glass and the huge Gothic windows provided both a practical light and an ethereal light created by the coloured and decorated panes. During the Dissolution of the Monasteries in the 1530s, this window glass was either sold and reinstalled in parish churches or private dwellings or was stripped of the lead came (that held the different coloured 'quarries' together) and dumped (Fergusson, Harrison and Coppack, 1999, pp. 180, 229). Some of this 'dumped' window glass has been retrieved from dissolution deposits during 19th, 20th and 21st century excavations, much by the Office of Works/Ministry of Public Buildings and Works in the early-20th century, and the glass is currently held in English Heritage and museum archives. Fragments of excavated window glass are usually small, corroded and difficult to date. As such they are generally under-studied and unpublished yet hold enormous potential for understanding many aspects of glassmaking and of glass use. Because the fragments are small they can be easily analysed, and compositional data can sometimes be used to assign provenance and elucidate the trade of glass in the medieval period. Most consumption studies of window glass are small case studies scattered over a broad timeframe. Surviving medieval window glass is rare, glassworking evidence is localised and generally rare, and Historic England (HE) highlights the potential for further study on trade and industry resource consumption, and decorative schemes (2011). This Doctoral study looks at the wider picture of glass consumption at multiple high status monastic sites to enable patterns of use to be seen and interpreted in a changing historical context.

1.1 Research aims

The study examines the consumption of English window glass at high status sites using case studies of excavated window glass dated from the 12th to the 16th centuries from selected Benedictine and Cistercian abbeys across England.

Four Benedictine and three Cistercian abbeys were selected from four geographically different areas across England. Each area had access to differing trade routes and glassmaking areas and thus the consumption of window glass by the monasteries from different areas and of different religious orders can be compared and interpreted. The research results identify and date glazing episodes at each site, assign provenance where possible to broad areas or countries, and characterise the glasses physically. The resultant profiles are interpreted in the context of the social, political and economic background to the period.

The research also expands the corpus of medieval window glass by way of scaled photographs of each of the 284 fragments of glass, plus black and white illustrations of the 238 decorated glasses. The development of techniques to interpret excavated window glass by way of its decoration and tight-dating using an Evidence Informed Dating Framework (EIDF), developed here, is therefore an important aspect of the study and its legacy to enable information held within fragments of excavated window glass from other sites and studies to be made more accessible.

1.1.1 Research questions

The research questions are summarised as follows:

- What is the source of the window glass used at monastic sites in England and how did this change over time?
- Was English window glass used at the high status monastic sites?
- When was it used, how was it used and what are the physical and compositional characteristics of the glass?
- What influenced the choice of glass source considering proximity to the glassmaking centres, influence of religious order, quality, price and availability?
- What do the results reveal about the glass making industry in window glass production in England in comparison with the continental glasshouses?

1.1.2 Objectives

The objectives of the study are to:

- Undertake an extensive study of medieval window glass from multiple high status monastic sites: four Benedictine and three Cistercian abbeys across England from four geographically distinct areas
- To understand the chronological structure of each sample set

- To understand the production technology of each glass by way of a macro and microscopic examination
- To use a rapid, non-destructive analytical technique to obtain chemical composition
- Use results from analyses to characterise glass from each site and provenance to a regional production centre or country
- To discuss the use of glass at high status monastic sites with reference to the historical background of the study period
- To examine how, when and where English glass was used and discuss reasons why it was used at high status sites

1.1.3 Methodological objectives of the research

The research is a multi-analytical and interdisciplinary study using data gathered through stylistic, technical and chemical analyses.

A stylistic analysis is undertaken to date the glasses based upon the applied decoration. This is done using established techniques borrowed from art history, namely dated parallels whereby a comparison of the applied decoration is made with that of usually extant, in-situ windows, and also using techniques developed for the study. These include the use of a computer-aided mapping application called Procreate to quickly and accurately draw decoration that may be obscured by layers of corrosion material and concretions from the burial environment, and also Evidence Informed Dating Framework (EIDF), to fine-tune dating by correlating glazing episodes with relevant site-specific historical information.

The technical analysis includes a macro and microscopic examination to characterise the glasses physically, making use of elemental mapping and Keyence microscopy to note colour, thickness, quality of finish, composition of the paint, degree of corrosion and evidence of how the glasses were made.

The chemical analysis uses micro X-ray fluorescence (micro XRF) to determine the major, minor and some trace element of the glasses. This analytical technique is non-invasive, rapid and reliable when measuring elements with a high atomic mass. Lighter elements such as sodium are less well characterised. The results produced here are considered semi-quantitative but scanning electron microscope (SEM) with attached energy dispersive spectrometer (EDS) was used on selected samples to corroborate the results from the micro XRF analysis.

1.2 Overview of the thesis

The introduction to the doctoral thesis provides the context for the study and the research aims. Chapter two presents details of the inherent characteristics of glass and of glassmaking in northwestern Europe in order to illustrate the regional differences in glass composition. Chapter three reports on the socio-economic, political and architectural background to the study period, providing a context to glass consumption and glassmaking from the 12th century to the Dissolution of the Monasteries in the 1530s. In the absence of purchase records relating to specific glazing commissions at the abbeys, the study glasses are dated on their applied decoration; chapter four explores this chronology of the decorative elements of stained glass and provides an overview of the process of producing a window in the medieval period. The decorative elements form an initial basis for dating the glass for subsequent analysis. In chapter five, the religious, economic and geographical backgrounds to the seven study sites are described, the archaeology and the retrieval of the glass fragments used in the study are detailed, and a summary of the assemblages is given. This gives the background information for each site for subsequent discussions on and interpretations of glass use (Chapter nine).

The second half of the thesis concerns data collection and interpretation. The methodological chapter (chapter six) outlines sample selection, the analytical techniques used in the project and the statistical methods used. In chapter seven the results of the stylistic, technical and chemical analyses are presented on a site-by-site basis, and in chapter eight, a tentative provenance is established by cross-matching the composition of the study glasses with the regional data (from chapter two).

Chapter nine presents an interpretation of the results, and a discussion of consumption patterns relating to glass type, colour, and workshop practice, proximity to glass production centres, the use of glass by different orders and the different consumption patterns relating to the glasses' country of origin. An overview of the consumption of English glass in a monastic setting is presented. The concluding chapter (chapter ten) gives a summary of the key findings, assesses the methodology and indicates areas for future study.

Chapter 2

2. The chemistry of glass and glass production

2.1 Introduction

Glassmaking is a complex and specialist process that involves heating the raw materials to a sufficiently high temperature so that they melt and the molten glass can then be formed into different shapes. Glass has been made and traded for over three and a half thousand years and from the first century AD window glass has been manufactured. The production of glass from the raw materials in England has considerably less history with evidence of a nascent industry from the 13th century. This chapter discusses the inherent characteristics of glass before examining the ingenuity of the early European glassmakers in the medieval period. The locations of the principal medieval glassmaking areas are identified and the contextual relationship between the land and the people who worked in the glass industry is considered before a closer analysis of the English industry is made.

2.2 Raw materials

Glass can be made from many different ingredients and thus it is generally not defined by its chemical composition but by its physical properties and atomic structure (Brill, 1962, p. 127). Glass is a non-crystalline solid that cools down quickly so that molecules do not have the chance to order, and glass solidifies without crystallising. As such, it has the mechanical rigidity of a crystal but the random, irregular molecular structure of a liquid. Because there are no crystal boundaries, glass is transparent, it does not cleave in a preferred direction and is brittle, but importantly, because of its vitrified matrix glass is durable and impervious to liquid. In terms of working properties glass does not have a sharp melting point but is viscous and has a long working range and can be re-melted and recycled (Pollard and Heron, 1996, p. 154; Fernández-Navarro and Villegas, 2013, p. 3). Glass is a unique material and while the recipe may have changed and adapted, for instance to the availability of the raw materials, all historic glass is made from a combination of three major components: a network former, a modifier and a stabiliser.

2.2.1 Former

The network former is the main ingredient of glass. In historic glass the former is silica in the form of silicon dioxide (SiO_2), which was easily available in the form of sand or crushed quartz. Silicon and oxygen are strongly bonded in a tetrahedral pyramid structure with a silicon atom in the centre of four oxygen atoms (Newton and Davidson, 1989, p. 5; Wedepohl, Simon and

Kronz, 2011). Glass is a build-up of these tetrahedra whereby oxygens on the corners, called bridging oxygens, are shared – or bridged with a neighbouring oxygen atom/tetrahedra. Because of the rapid cooling, the network of Si-O tetrahedra is random and irregular, and some oxygens remain unbridged, termed non-bridging oxygens. The unbridged corners are therefore available to form chemical bonds with other elements introduced into the mix (Zanini *et al.*, 2023. P. 2).

2.2.2 Modifier

The modifier lowers the melting point of the former, thus making it much easier to melt the silica. Because of the strong Si-O bonds silica has a high melting point of around 1700 ^{o}C, a temperature unachievable in ancient furnaces or even some modern furnaces (Smedley, Jackson and Booth, 1998, p. 7; Henderson, 2013, p. 23). A modifier or flux, in the form of an alkali such as potassium lowers the melting temperature of silica by filling the unbridged corners of the tetrahedra and so weakening the Si-O strand (Frank, 1982, p. 10). The flux also improves the workability of the molten glass enabling it to mix and fuse more easily. From the 12th century glass produced in southern Europe was often manufactured from imported halophytic plant ashes rich in sodium (Wedepohl, 2010, p. 63). In northern Europe a wood ash flux gradually replaced the soda-lime recipe and from the 11th century was the major flux used in window glass production (Grunewald and Hartmann, 2014, p. 50). The wood ash was rich in potassium, magnesium and calcium, and a smaller proportion of sodium, and beech and oak were commonly used as well as bracken (e.g. Stern and Gerber, 2004; Smedley and Jackson, 2006; Colomban et al., 2010; Wedepohl, Simon and Kronz, 2011).

2.2.3 Stabiliser

The glass stabiliser is an alkali earth oxide, such as calcium, aluminium, magnesium, barium or lead, that increases the durability of the glass, prevents the naturally soluble sodium silicate from dissolving in water and increases resistance to corrosion (Moretti and Hreglich, 2013, p. 30) (see section 2.5 below). In historic glasses the predominant stabiliser was calcium oxide, or lime, which was found naturally in small amounts in river sand, larger amounts in beach sand, but significant amounts in wood ash (e.g. Jackson and Smedley, 2008). Thus, until it was documented that crushed limestone was added to the batch in the 17th century (Merrett, 1662, p.14) glass was essentially a two-ingredient material. Colourants, de-colourants, opacifiers and refining agents could be added to the batch, either intentionally or naturally through other raw materials, to alter the appearance of the finished product. This is discussed in the following section.

2.3 The production of medieval glass

Glass characterised by a wood ash flux can be called forest glass and has a high wood ash (high in potassium) to silica ratio during manufacture of approximately two to one by weight. The

higher amount of potassium flux brought the melting temperature down, which suited the earlier furnace technology (see below, 2.3.2). The few surviving textual sources provide a basis for our understanding of how forest glass was made, including what raw materials were used, how they were selected and processed, the furnace designs and procedures for colouring glass. Archaeological excavation and scientific research have thrown light on the processes, and experimental work has have tested some of the assumptions regarding recipes and workshop practices that have come from the textual sources

2.3.1 Textual sources

The most important medieval literary source is *De Diversis Artibus* (The Various Arts), written in the 12th century by Theophilus, a German Benedictine monk generally accepted to have been the skilled metalworker Roger de Helmarshausen and intended for the use by monastic craftsmen (Hawthorne and Smith, 1979; Crewe, 1987, p. 9). Book two (of three) of *De Diversis Artibus* is the earliest surviving technical description of glassmaking and glazing in the medieval period in which Theophilus describes many aspects of the glassmaking process (as discussed below) (Brown, 2019). Other texts on glassmaking include *De Coloribus et Artibus Romanorum* (The Colours and Arts of the Romans), which was written in the 12th or 13th century in Italy by an author called Eraclius and translated from Latin into English by M.P. Merrifield in 1967. The treatise explains some of the glassmaking practices including the preparation of the batch using a wood ash of saplings and fern, colouring the batch using burnt copper filings, and manufacturing vessels and window glass (Merrifield, 1967, p. 202-216). A key visual source used to understand the glassmaking process and the arrangement of the glassmaking site is a depiction of a Bohemian furnace scene in a publication entitled Travels of Sir John Mandeville, dated to around 1410 (discussed below in section 2.8).

Although dating to after the study period, the following sources are worthy of mention**:** *De Re Metallica by* Agricola, who, in a translated edition by Hoover and Hoover (1950, p. 586) describes using the ash of beech oak or pine if salt or halophytic plants were not available. It is thought that in 1530 he owned a copy of *De Diversis Artibus* manuscript while resident at St Pantaleon monastery in Cologne; *The Art of Glass by* Neri, (1612), which was translated by Christopher Merrett in 1662 describes using ashes of beans, bramble and fern (Merrett, 1662, pp. 71–73); Biringuccio was an Italian master craftsman who in 1540 wrote *De la Pirotechnia*. The book focuses on the art of metallurgy but a chapter is devoted to glassmaking in which Biringuccio describes both the southern tradition of using halophytic plants for the flux, and a brief account of forest glass production (Merrett, 1662; Smith and Gnudi, 1990, pp. 126–133). The texts presented above have slight differences in the recipes, in particular in the choice of flux. The authors were not glassmakers however, and many of the glassmaking processes they describe have been tested; nonetheless, the techniques described by Theophilus are accepted as a good foundation to explain medieval glassmaking practice in northwestern Europe in the medieval period (for example, Smedley, Jackson and Booth, 1998).

2.3.2 Sourcing and preparing the raw materials

Theophilus describes collecting sand from water, interpreted by Hawthorne and Smith (1979, p. 52) as riverine sand, and cleaning it of earth and stones. Some impurities were too difficult to remove such as iron, which caused a mostly unwanted green colouration of the glass. The purest sands were therefore more desirable. Winbolt (1933, p. 53) describes the Wealden quarried sand as 'irony', and inferior. The glass recipe according to Theophilus was one part of sand mixed with two parts of beech wood ash, substantiated in experimental studies as by weight (Smedley, Jackson and Booth, 1998, p. 6).

Wood ash or the ash from terrestrial plants was used for the flux (Henderson, 2013, p. 48). Wood ash was collected from the burning of trees; Theophilus describes the cutting of beech logs (Hawthorne and Smith, 1979, p. 49), and Agricola describes hollowing out a mature tree at the six feet mark, setting a fire inside and burning the whole tree (Hoover and Hoover, 1950, p. 586). Ashes were also bought from an outside source, for example from an ash burner who may have supplied other industries such as soap or fertiliser production (Clark, 2006, p. 170), and a sales record of 1479 records the sale of 'ferne' to a Staffordshire glasshouse for 5 shillings (Welch, 1997, p. 2). Forest floor plants such as ferns are particularly high in potassium and accordingly were cut when they contained the optimum amount of the nutrients: Eraclius, for example, describes cutting fern before the Feast of John the Baptist on June 24th (although this may have been later in the cooler climes of England) (Merrifield, 1967, p. 212).

Since the wood ash is derived from the burning of trees, the composition of the ash is dependent on the landscape and the chemistry of the different habitats. Wide compositional variation can be seen within the same tree species across different times of a growing season and year on year, and it is therefore difficult to determine the exact species used in a recipe from a chemical analysis of historic glass since there is much compositional overlap (Smedley, Jackson and Booth, 1998; Henderson, 2013, pp. 48–51). Further uncertainty arises depending on which part of the tree was used: trees store nutrients differently and the part of the tree that was ashed, such as the bark, twigs or trunk would influence the composition. The amount of calcium and silica, for example increases 'from trunk to leaves' (Colomban *et al.*, 2010); and the amount of potassium, which is the primary alkali found in wood ashes, is highest in the trunk of a mature tree (Wedepohl, 1998; 2010).

2.3.3 Fritting and melting

Fritting, as described by Theophilus, is a pre-melt stage involving the dry heating of the sand and wood ash mix to initiate a solid state chemical reaction. The frit does not melt but some impurities, unreactive inclusions and water are vapourised. Although not all glassmakers undertook fritting there were many advantages including improved homogeneity and a quicker melt because the silica and potassium had combined earlier (Smedley, Jackson and Booth, 1998). The frit was then put into crucibles and placed on the sieges in the furnace (see

below). Crucible fragments have been found at many former production sites, for example in the Weald, and show that they were made by hand (not thrown) using fire clay with a sand temper. In Staffordshire, for example, there was abundant and suitable fire clay available; archaeological investigations at Little Birches retrieved fragments of 13th/14th century crucibles that are barrel-shaped and 16th century crucibles, which are larger, with thicker walls and a turned-out rim (Welch, 1997, p. 16). The furnace temperature was achieved through the gradual feeding of wood over several days (Polak, 1975, p. 15); de-gassing, or bubbling started at around 800°C and the batch melted at around 1200°C, a temperature that was typically achieved in a medieval furnace (Wedepohl, 2010, p. 66).

Cullet that was brought into glasshouses for adding to the glass batch, as seen at Little Birches in Staffordshire for example (Welch, 1997, p. 1), included broken vessels, and window glass, some from church windows that could have come from various sources, but Kenyon suggests some of it could have been French (1967, p. 18). Cullet was used primarily to lower the melting temperature of the batch thus saving time and fuel and also slowing the deterioration of the crucibles by way of less exposure to prolonged and intense heat (Kenyon, 1967, p. 18). Production waste, glaziers' off-cuts and broken vessels were also recycled. Some of the cullet used in medieval glassmaking will itself have contained recycled glass from an earlier period. The dilution of the glass composition due to added cullet results in greater variation and more compositional sub-groups, as well as increased difficulty in identifying the source of the raw materials (Smedley and Jackson, 2002, p. 222). Until the end of the 12th century, Roman tesserae were added to the batch and used as a source of colour, in particular blue (Gratuze, Pactat and Schibille, 2018, p. 13).

2.3.4 Furnaces

The type of furnace used in southern Europe, as described by Agricola in 1556, was domed with a circular footprint (Hoover and Hoover, 1950, p. 587) but in northwest Europe the furnaces, as described by Theophilus were often tunnel-shaped, with a rectangular footprint and a central firepit running along its length (although not completely upheld by archaeological evidence and this design is partly based on conjecture). Raised platforms, or sieges were built on either side of the firepit to hold the crucibles containing the molten glass. Theophilus also describes con-joined and separate furnaces for different jobs (and thus requiring different temperatures) that included a furnace for melting the batch with a smaller part of furnace for fritting, an annealing over or lehr, and a furnace for flattening cylinders for making broad window glass (Hawthorne, 1965, p. 49-52, section 2.6.1 below). A furnace might only last between nine and 24 months because of the wear and tear from the intense heat. Where there was no or little naturally occurring building stone, in the Weald for example, the furnaces were dismantled and reconstructed in new areas when the nearby supply of wood was exhausted; 'following the fuel' (Kenyon, 1967, p. 15).

Other infrastructure and tools that would be needed for the production of forest glass included a marvering table for working of the glass, a grozing iron, blowing iron, puntee and pincers (see glossary). Flints found in the Weald may have been used for marking or cutting the glass (Winbolt, 1933, p. 58). Postholes from a 16th century furnace at Bagot's Park are evidence of an open-sided roofed structure and further post holes marked a shed and rack, which Crossley (1990, p. 228) says was for storing crowns. Crossley also comments that the arrangement of the glass workshop is similar to that depicted in the Mandeville miniature (below, section 2.8). Knightons in the Weald, dated to around 1550 also has evidence of a store, shed and a working floor indicative of a well-ordered site (Merchant, 1998, p, 86, 93).

2.3.5 High lime, low alkali composition (HLLA)

In the 14th and into the 15th century in Germany, and from the mid-15th century in eastern France there was a gradual change to the forest glass composition whereby the amount of potassium reduced and calcium and silica increased (Barrera and Velde, 1989). This is referred to as high lime, low alkali glass (HLLA). Wedepohl (2010, p. 66) proposes that the change may have been forced on the glassmakers because of increased competition for wood (for example from ironmaking). Several studies attribute the changed composition to changes to the recipe, the source of the raw materials and improved workshop practices; Wedepohl and Simon (2010) and Wedepohl (1997, p. 252), for example suggest that as part of forest reorganisation lower quality wood such as spruce was used; Hartmann (1994, cited in Adlington, 2019) suggests that limestone was added although Meek (2011, p. 158) found that the evidence for this practice at this time is inconclusive. Mortimer (1997, p. 39) states there is no documentary evidence of added limestone in glassmaking until the late 17th century but suggests that plant ashes from oak (or heather) could have been added because they are calcium-rich; this is tested and reported on by Jackson and Smedley (2002), and Stern and Gerber (2004, p. 147) who report high calcium levels in ash made from beech trees grown on limestone. The change in composition was concomitant with the development of hotter furnaces meaning that less potassium flux would have been required to melt the sand. The composition of HLLA glasses in this study is determined using Adlington's formula: $CaO/[CaO+K_2O]$ ratio above about 0.75, and about 10% or less alkali (Na_2O+K_2O) (2019, p. 57, footnote 9).

Known furnace developments were two-fold: smaller, more compact furnaces that were quicker to heat and required less fuel, and multi-chamber furnaces that provided extra space for fritting and the pre-heating of crucibles and also insulated the main melting section from heat loss. Crossley and Aberg (1972, p.115, 120-1) state that winged furnaces also provided a chamber for annealing and were used solely for vessel making as the forming of window glass required more floor space between the main furnace and the lehr, or annealing oven, to work the glass into sheets (see below, 2.5.1). The change to the HLLA recipe was not seen in English glassmaking until the second half of the 16th century and furnaces in the Weald from this period include a late 16th century furnace at Vann Copse, Hambledon (Kenyon, 1967, p. 193; Willmott, 2005, p. 78).

2.3.6 The use of salt, sodium chloride (NaCl)

Lagabrielle and Velde (2005, p. 341) refer to the addition of salt (sodium chloride, NaCl) to 13th century glass (containing above 1.5% sodium) from Normandy for better fluidity and fining (removal of bubbles) (Gerth et al., 1998), and in the 15th century, Wedepohl and Simon (2010, p. 90) state that salt (NaCl) was added at start of melt to supplement the low potassium content in the production of the German HLLA glass. The textual evidence is however limited, although Agricola reports the use of salt in glassmaking in the 16th century (Wedepohl, 2003, p. 29).

2.4 Colouring glass

A range of coloured glasses, including red, blue, murrey (pink-purple), amber, yellow and green were produced by medieval glasshouses. The glasshouses were possibly specialist makers of coloured glass who understood how adding colourants in the form of metals such as copper and cobalt could change the colour of the glass, or how the careful control of the furnace atmosphere in terms of the level of oxygen, temperature and the duration of the melt could produce different colours from the naturally present colourants such as iron and other raw materials in the glass (e.g. Henderson, 2013). There are no surviving chapters by Theophilus on colouring glass using metals, but Eraclius describes how to produce different coloured glass (Merrifield, 1967) and Book Three of Neri's *The Art of Glass* is devoted to the production of some colours of glass including red (Merrett, 1662). Theophilus does however describe the production of yellow and purple glass using the temperature of the furnace and the duration of the melt (Hawthorne and Smith, 1979, p. 55). Yellow, or amber was produced in a reducing furnace atmosphere with a low amount of oxygen achieved by restricting or dampening the inflow of air into the furnace, and murrey was produced in an oxidising atmosphere. In such ways many colours in the medieval glass repertoire could be made from the glass forming ingredients, as well as from the addition of metals. This is shown in table 2.1.

Table 2.1 Some of the colours that could be made by medieval glassmakers from the glass forming ingredients and the addition of metals

Colour produced from the glass forming ingredients		**Reference**
Murrey	High levels of manganese in oxidising conditions	Weyl, 1951
Amber	High level of potassium flux in a reducing atmosphere; also, using added carbon	Paynter and Jackson, 2018
Green	From the iron in an oxidising atmosphere	Weyl , 1951
Colours produced from the addition of metals		
Red	Copper or iron in a reducing atmosphere	Kunicki-Goldfinger et al., 2014 Wedepohl, 2010
Blue	Cobalt, which may be derived from scrap copper alloys including brass	Gratuze, Pactat and Schibille, 2018; Wedepohl and Simon, 2010
Green	Produced from the addition of copper in a reducing atmosphere	Wedepohl, 2010

Red glass that was coloured all the way through predominantly using copper was made until the 13th century. Copper is a very powerful colourant and in a window against the light appeared opaque. Techniques were thus developed to make the glass translucent by layering red and colourless glass together (Charleston, 1991, p.244). Initially this was as multi-layered or striated (and sometimes deliberately streaky) glass, and subsequently as a single layer of red glass with one or two layers of colourless glass. This is called flashing, and blue and purple glasses were also flashed from the late-14th to early 15th century. The chronology of these techniques, from opaque to flashed red (assigned 'types' by Kunicki-Goldfinger et al. (2014)) can be used to assign a broad date range (table 2.2).

Table 2.2 The chronology of red glass using types assigned by Kunicki-Goldfinger et al., 2014

Production of red glass	**Kunicki et al. (2014) red type**	**Date**
Opaque	N/A	TAQ around C13
Striated or streaky	A	C12-14
Flashed; a single layer of red glass overlying colourless glass or sandwiched between two layers of colourless glass	B	TPQ late C14/early C15

2.4.1 De-colourising glass

The natural green tint (from iron) of much forest glass can be counteracted by manganese. There are no records of the deliberate addition of manganese in glassmaking before Biringuccio's account in the 16th century (Smith and Gnudi, 1990, p. 132) but manganese can be derived from the raw ingredients in concentrations of up to 1.5% (Spencer, 2020, p. 70). Very pale green and colourless glass may therefore have been achieved through judicious selection of the raw materials: beech (and spruce) has a high level of manganese, for example (Jackson and Smedley, 2008, p. 120).

2.5 Forest glass corrosion

Medieval forest glass has low stability because of its high alkali (primarily potassium), low silica composition. As such it is vulnerable to attack from water, called hydrolytic attack: in-situ as rain or condensation and also from groundwater in the burial environment. Hydrolytic attack is a chemical process in which the water molecules attack the silica-oxygen bonds in the glass and in this process hydrogen ions from the water exchange place with the alkali ions in the glass. The hydration of the glass matrix leads to the dissolution of the silica network, and the alkali ions, such as calcium, magnesium, sodium and potassium, which are highly mobile, leach from the surface creating a layer of alteration (Greiner-Wronowa et al., 1995; Sessegolo et al., 2020; Zanini et al., 2023; Cilova *et al.*, 2015, p. 153). This leads to the corrosion, or weathering of the glass. The degradation of the glass is a gradual process taking place over years, starting from the outside of the glass and working inwards. The degree of alteration ranges from slight dulling, or discoloration to the far-reaching modification of the silica network whereby the glass has deteriorated to such an extent that it appears sugary in texture. These are discussed below.

The extent of corrosion is dependent in part on the composition of the glass as well as the surrounding environment. As discussed above, the dominant alkali in forest glass is potassium;

potassium ions are larger than hydrogen ions, and thus in the ionic exchange the volume of the glass is reduced and is weakened as a consequence. Glasses with sodium as the predominant alkali are more durable and deteriorate more slowly. This is because sodium ions are relatively large and the differential between the sodium and hydrogen ions is relatively small; in ion exchange the impact on the glass matrix is less severe (Newton and Davison, 1989, p. 136). It should be noted however, that the amount of sodium in forest glass is small: 2% or less is typical. High lime, low alkali (HLLA) glasses are less sensitive to weathering because of the lower ratio of potassium to silica (discussed above, 2.3.5). The extent of corrosion is also dependent on the atmospheric conditions that the glass has been exposed to while in-situ and the conditions in the burial environment. These are discussed as follows.

2.5.1 In-situ weathering

Circular pits, often filled with weathered crust on the exterior side of the glass indicate that the weathering of the glass has occurred in-situ (Verney-Carron *et al.*, 2023, p. 2) (figure 2.1). Here atmospheric weathering in the form of rainwater, condensation and high humidity is responsible for any degradation. The circular pits range in size from less than 1 mm to 5 mm wide and may join together to form a network of larger pits and channels on the exterior surface, eventually covering the entire surface. A white or darkened band around the grozed edges of the excavated window glass, a lead shadow, can sometimes be seen and indicates where the lead came has protected the glass underneath from the weathering phenomena (figure 2.2). In a secondary stage of in-situ weathering the leached alkalis react with elements in the environment, notably sulphur dioxide and carbon dioxide that are in the atmosphere or dissolved in rainwater. The reaction forms calcium, carbonate and sulphate crystals, for example, calcite and gypsum, seen as a white, powdery coating on the surface of the glass (Verney-Carron *et al.*, 2023, p. 8)

2.5.2 Burial environment corrosion

The impact of the corrosion of the glass in the burial environment can vary from slight dulling, iridescence and localised spots of corrosion, to becoming severely corroded with a thick, opaque weathered crust covering the entire surface of the glass (Zanini *et al.*, 2023) (figure 2.3). The process is cyclic with alteration layers of weathered crust building up and the glass may eventually devitrify and appear granular. A crust that covers the edges of the glass is evidence that corrosion took place after the glass was broken (figure 2.4). In this study, this is most likely from the time of its removal from the window at the Dissolution of the Monasteries in the 1530s. Different forms of corrosion on some examples from the study are shown in the figures below and referenced in the text (figures 2.1 to 2.6).

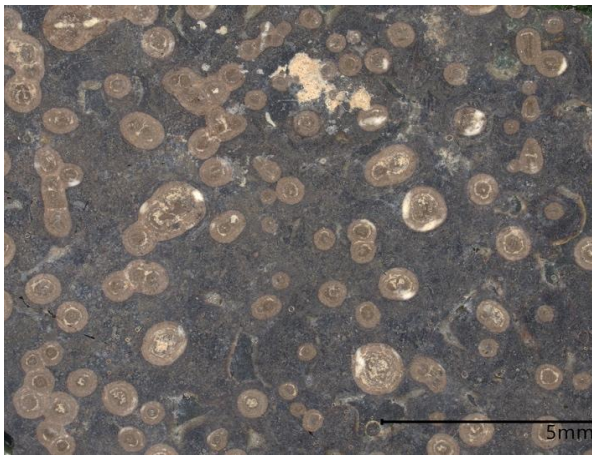


Figure 2.1 ALC 22, in-situ pitting

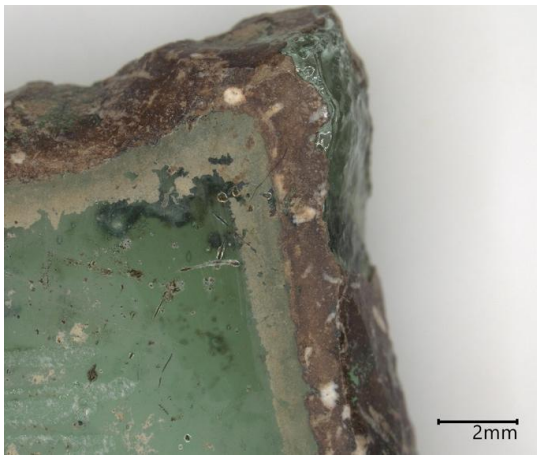


Figure 2.2 L39, lead shadow around border of glass indicating in-situ weathering

Figure 2.3 R51, glassy core exposed through weathered crust

Figure 2.4 R51, weathered crust extending over edges demonstrating post-depositional corrosion

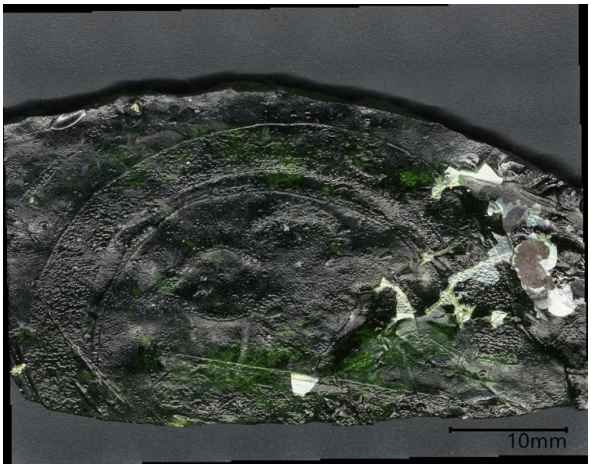


Figure 2.5 R53, palimpsest of decoration

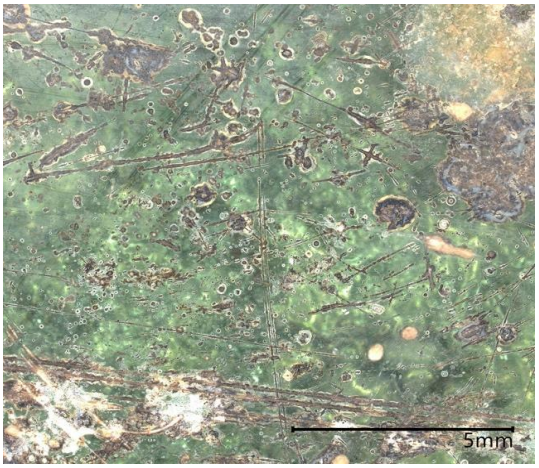


Figure 2.6 ALC20, mechanical damage and scratches

The crust may also delaminate through a build-up of the leached layers, or it may flake or crack to expose the glassy core. The painted decoration may at the same time flake from the glass; in some cases, the paint underneath the crust has protected the glass creating a palimpsest of the decoration (Graves, 2000, p. 398) (figure 2.5).

Localised weathering conditions in a dissolution deposit that consists of a mix of building debris may explain why some glasses are more corroded than others from the same compositional group. Limestone or lime mortar can create slightly alkaline conditions that would have degraded glasses in close proximity, and masonry or timbers for example, may have shielded glasses from rainwater or ground water that would cause corrosion. Equally, the in-situ weathering of installed glass may have been affected by localised conditions such as the exposure to the elements, some windows more than others depending on orientation and whether the windows were shielded by other buildings. The glass itself may have localised weathering dependent on for example, the presence of silver stain or lead came, which may protect the glass underneath both in situ and in the burial environment.

Further types of glass alteration that are seen commonly in forest window glasses include discolouration caused by the in-situ oxidation of manganese in manganese-enriched glass; discolouration from iron in the soil of the burial environment; surface concretions of mortar from the dissolution deposit; mechanical damage such as breaks and scratches (figure 2.6); also, post-depositional damage through inappropriate storage or poor handling. These factors are discussed in more detail in Wouters et al., (2012), Zanini et al., (2023) and Davison and Newton (2003).

2.5.3 Implications of corrosion on analytical study

The corrosion of medieval glass has implications for any analytical study. Features such as painted decoration or evidence of forming technique may be lost or obscured by the corrosion (Wouters *et al.*, 2012), and in a chemical analysis the weathered crust is not representative of the base glass since it has undergone chemical change. The techniques used to mitigate against corrosion in the glasses used in this study are discussed in section 6.2.4.

2.6 Methods of window glass manufacture

The two methods used to form window glass in the medieval period are the broad technique and the crown technique; both forms were made from the 4th century AD but crown was the quickest and easiest method (see Newton and Davison, 1989; Allen, Taylor and Hill, 2023, p. 49, 50, 54).

2.6.1 Broad glass

Broad glass was also known as Rhenish, Lorraine or Burgundy glass as these were regions where the glasshouses specialised in this technique. With this method (depicted in stages below, figure 2.7) a 'gather' of molten glass was blown into an elongated shape (stages 1 and 2) described by Theophilus like a long bladder (Hawthorne and Smith, 1979, p.55). Both ends were knocked off to create the cylinder, which was annealed and then scored down the middle with a sharp tool, possibly a flint in the medieval period or split with a red-hot iron (stage 4) (Kenyon, 1967, p. 19). The cylinder was then loaded onto a flat-bedded furnace to soften, open up and smooth down to create the flat pane (stage 5), which was then annealed for a second time. Larger cylinders could be made by swinging the molten glass in a channel using gravity to further stretch the glass (stage 3), before both ends were tapped off.

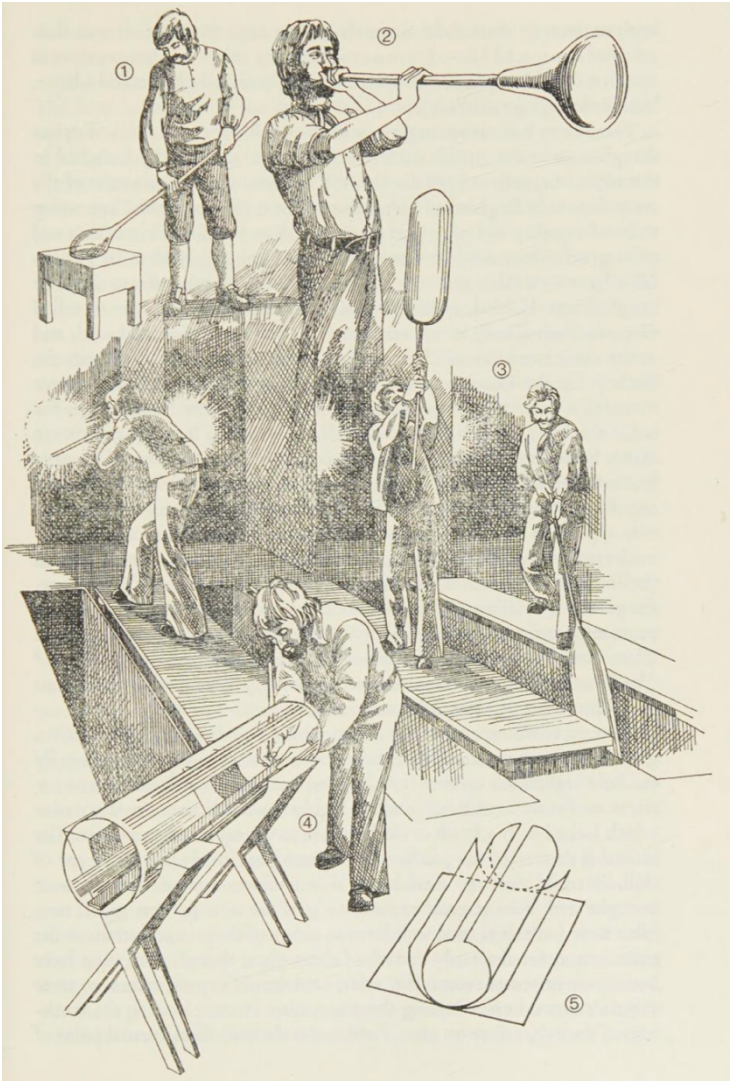


Figure 2.7 Illustration taken from Barker, 1977, p. 58 showing the stages involved in the production of broad glass

The morphological properties that help identify broad glass production in excavated glasses include (examples from the study shown below):

- a straight, fire rounded edge where the long edge of the cylinder slumped after it was cut (figure 2.8)
- dulling and indents on one side of the glass where the cylinder was in contact with the surface of the flat-bedded furnace during the softening and opening up process (figure 2.9)
- a consistent thickness throughout that is characteristic of a blown cylinder
- long internal bubbles in a linear alignment can sometimes indicate the stretch of the cylinder during production (section 2.6.3 below)

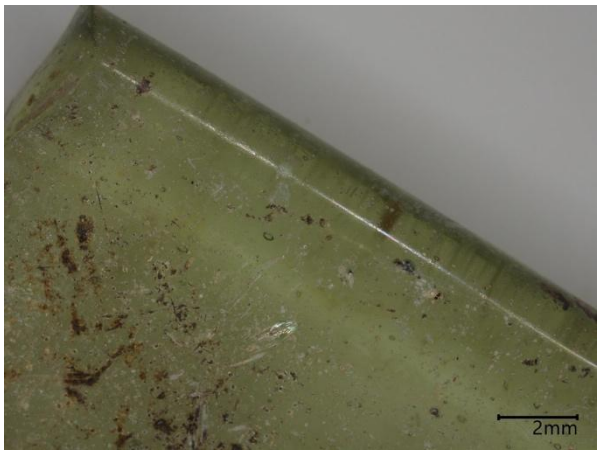


Figure 2.8 L37, straight-side fire-rounded edge indicating broad production

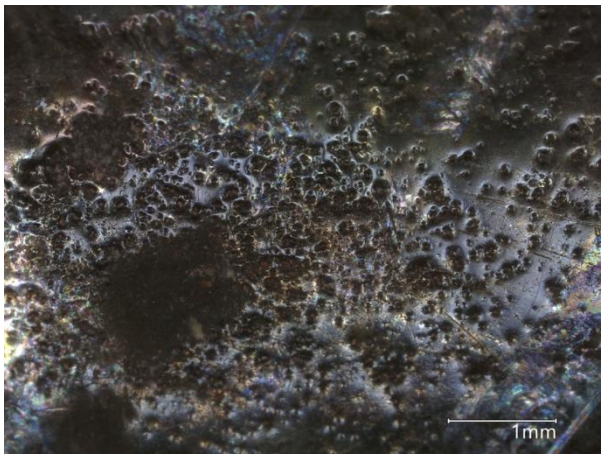


Figure 2.9 R10, indents on surface created during the opening up of the cylinder, or flattening process, in broad production

2.6.2 Crown glass

Crown glass was also known as Normandy glass or 'verre en plats' (glass plates), and in 15th century manuscripts it was referred to as French glass (Lagabrielle and Velde, 2005, p. 341). With this method (depicted below in stages, figure 2.10), a gather of molten glass was blown and then flattened into a small disc on a marvering table (stages 1 and 2). The disc was transferred to a pontil iron with a knob of glass to secure the disc (stage 3), then spun, using centrifugal force to enlarge it (stage 5). The crown was tapped off the end of the pontil iron and annealed (as depicted in Barker, 1977, p. 24). Fragments of 4th century crown window glass were excavated in the Middle East (Lafond, 1969) but there is no further evidence of its use until 1270-80 at the old Royal Castle in Rouen (now archived in the Musee de Cluny, Paris). The technique was not described by Theophilus (Lafond, 1969).

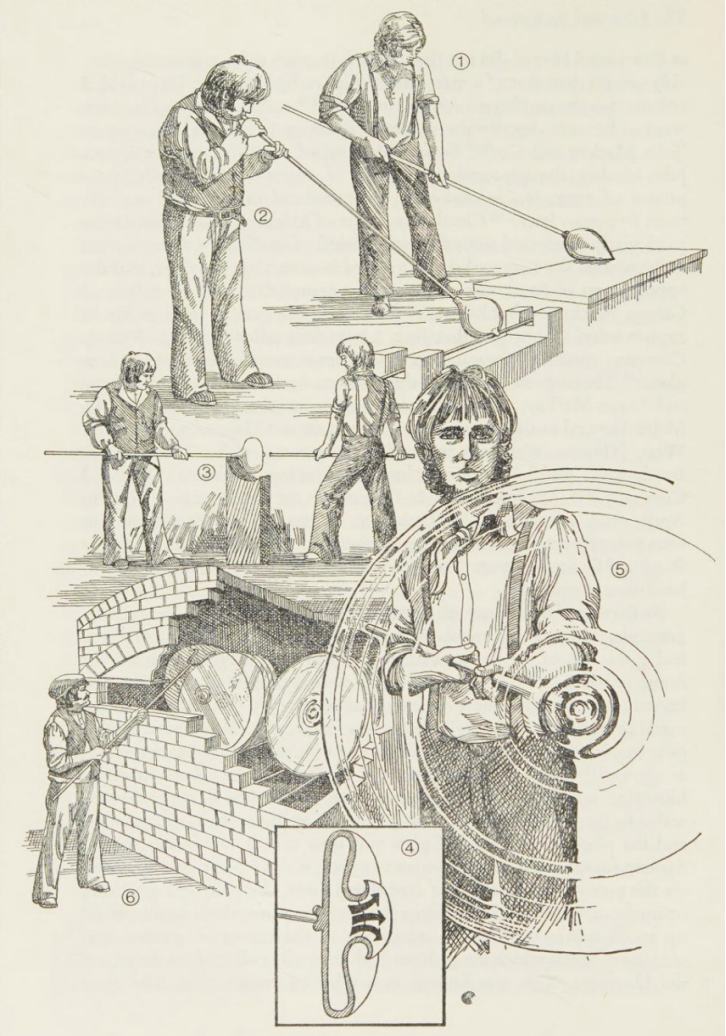


Figure 2.10 Illustration taken from Barker, 1977, p. 23 showing the stages involved in the production of crown glass

The morphological properties that help identify crown production in excavated glasses include:

- a fire-rounded edge in a similar manner to that seen in broad production except that the edge is rounded and as such generally too difficult to use in glazing (Crossley, 1967, p. 62); excavated fragments with rounded edges are thus much more likely to be broad glass
- the centres of crowns, called pontil marks or 'bull's eyes', which are sometimes excavated and may be glazier's waste (Bordesley and Hyde this study) (figure 2.11)
- a smooth and shiny surface on both sides of the crown with no pitting or indents, which gave crown glass a superior finish over broad glass
- ripples and concentric undulations around the diameter created during spinning, although very difficult to observe with small, excavated fragments
- tapering, with the thickness greater towards the middle of the disc and thinner at the edge where potentially the crown might be only 1 mm thick (figure 2.12)
- air bubbles seen in the glass in a concentric alignment

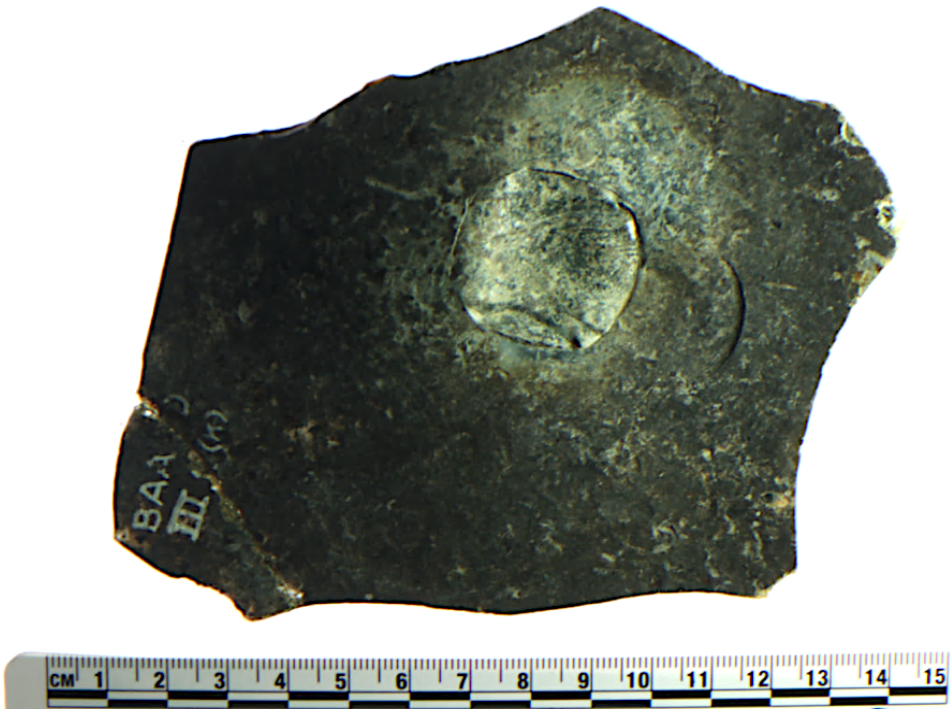


Figure 2.11 B42. Bull's eye from Bordesley showing pontil mark in the centre, indicating crown production

Figure 2.12 Fragment L36 (Louth Park) shows tapering profile indicating crown production, and tool marks (circled) that show that the glass was probably cut at the glasshouse while still fairly soft

2.6.3 Bubbles

Bubbles that are visible within the fabric of the glass are a potential way of discriminating between forming techniques. Crown glass uses centrifugal force to expand; any bubbles present in the glass will radiate in a spiral alignment and are more elongated at the edge of the disc. Conversely, cylinder production utilises gravity, and stretched bubbles are aligned vertically as the cylinder elongates (see Allen, Taylor and Hill, 2023). However, experimental window glass making has demonstrated that bubble orientation is variable in both forms (Taylor, 2023, email conversation with author, 17 January). In a cylinder, for example, bubbles at either end were shown to be at a right angle to the bubbles in the middle section (figure 2.13, circled a), and bubbles at intermediate angles were also present (circled b). This is because as the gather of glass is inflated at the start of the production process bubbles are aligned horizontally. They largely retain this alignment during the elongation of the cylinder because stretching is minimal at the ends. Only the relatively long thin bubbles in a linear alignment in the main body of the cylinder are reliable evidence of broad glass production (circled c). They are possible to observe even in small, corroded fragments using a magnifying glass. With crown glass, a circular arrangement of bubbles around the edge of a full crown can sometimes be seen (figure 2.14, circled). Bubbles towards the middle of the crown appear more rounded and orientation is extremely difficult to observe.

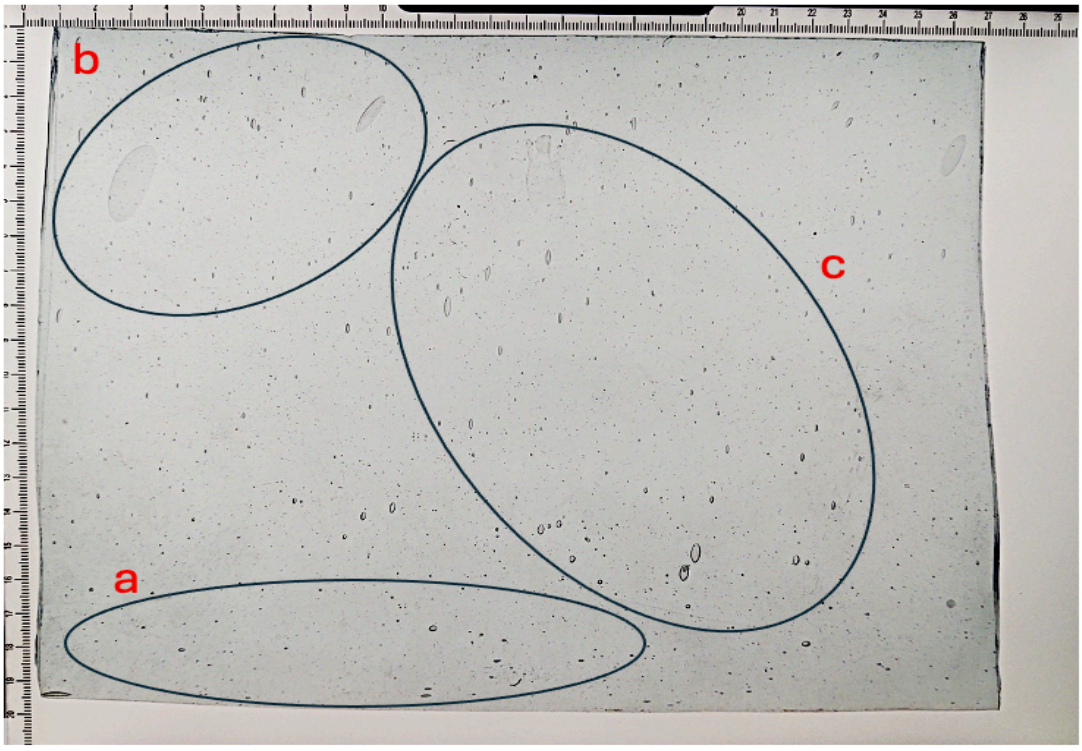


Figure 2.13 Experimental broad sheet produced by the Roman Glassmakers (2022) demonstrating the alignment of bubbles in the glass, as described above. The variety of angles shows that determining broad production through bubble orientation is difficult

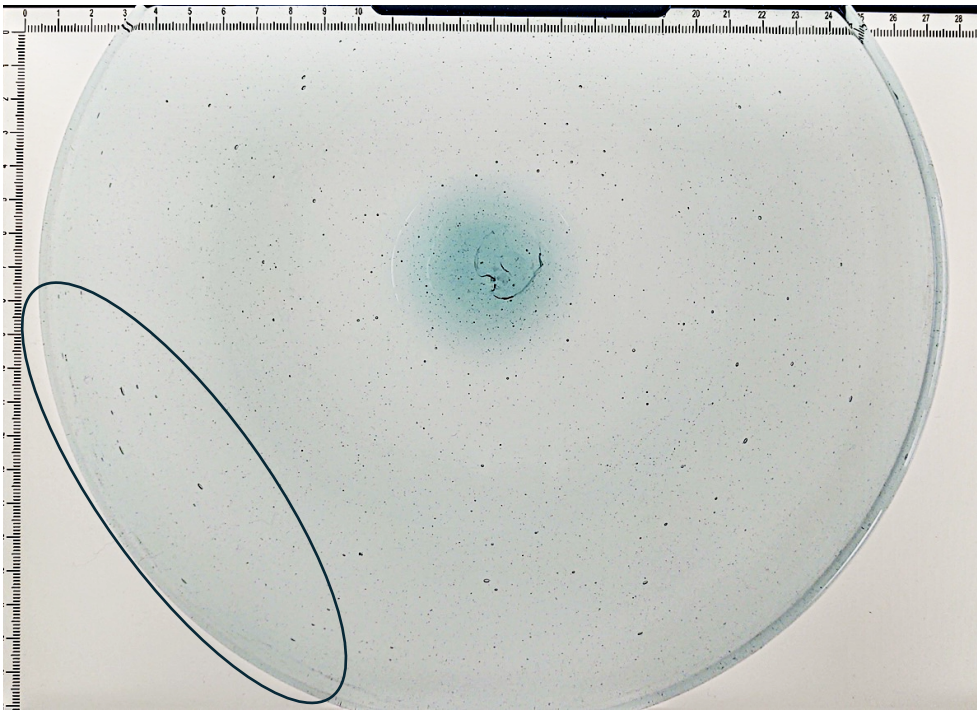
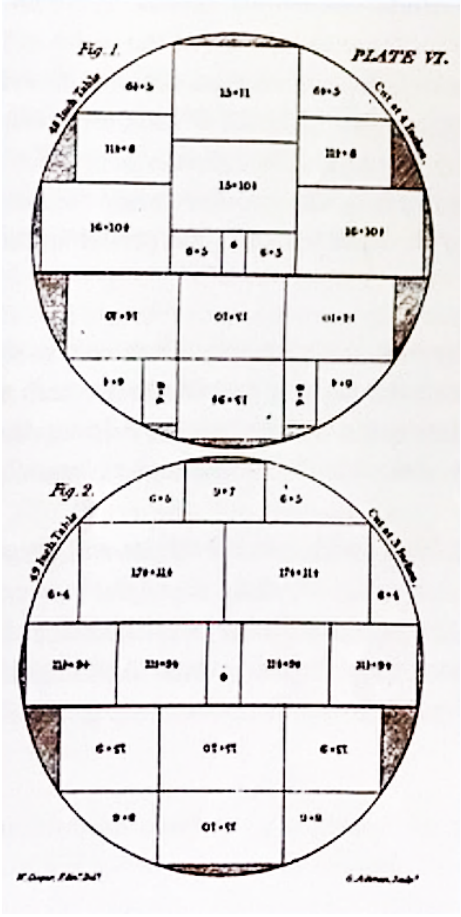


Figure 2.14 Experimental crown glass produced by the Roman Glassmakers (2022) demonstrating bubble alignment in crown glass. The curving arrangement of the bubbles can be seen only in a large section of the crown's edge, and thus determining forming process through bubble alignment in crown glass is difficult in the small, broken fragments from the study

Bull's eyes and curved crown edges found as off-cuts at production sites, for example Bagot's Park, Little Birches and Knighton's suggest that crowns may have been cut into quarries on site (Crossley, 1967, p. 62) (Welch, 1997, p. 19). This would enable safe transportation of the smaller quarries of glass and allow for the recycling of the off-cuts. Cooper (1835) as shown in Caen (2009) presents two examples of how a crown may have been divided up (fig 2.15, on left), and (Winbolt (1933, p. 59-60) proposes that a disc may have been cut into diamond-shaped quarries (figure 2.15, on right), although noting that this shape was not used in glazed windows until at least the mid-15th century. Possible evidence of crown-cutting in the study is shown in figure 2.12, where toolmarks on the inside edge were probably made at the glasshouse while the glass was still pliable (circled).



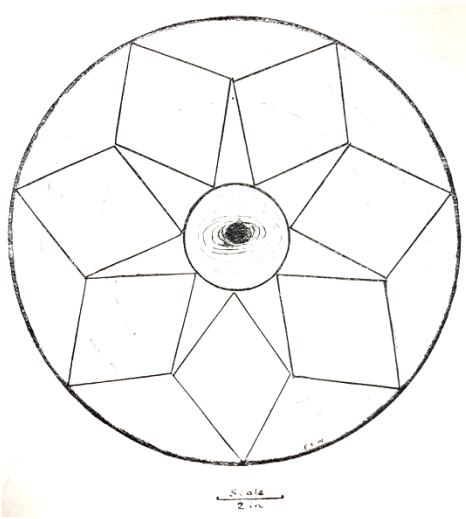


Figure 2.15 Left, Caen, 2009, p. 234 taken from Cooper's The Crown Glass Cutter and Manual, 1835, p. 46-7 showing the division of the crown into quarries at the glasshouse. Right, Wimbolt's suggested division of a crown into diamond-shaped quarries (1933, p. 59)

2.7 Location of Glass Making areas

Glasshouses in northern Europe were located in areas where the raw materials were most abundant. Sand or quartz pebbles, water plus refractory clay for making crucibles and stone (and refractory clay) for constructing the furnace were important, but the main consideration was access to wood primarily for heating the furnace and also for the flux. Estimates for the sheer amount of wood needed to produce one tonne of forest glass range from 150 to 250 tonnes (Cable, 1998, p. 324; Wedepohl and Simon, 2010). Much of England was forested during the medieval period and areas included parts of Lancashire, Cheshire, Shropshire, Staffordshire and Sussex (Fletcher, 1954, p. 338). In England, the two known main medieval glassmaking areas were the Weald on the Surrey-Sussex border and Staffordshire: the word 'weald' is derived from the German word 'wald' meaning forest (Collins, 2024) and Domesday Book records that one third of Staffordshire was wooded, much of it in the now-known glassmaking areas (Welch, 1997, p. 32).

Raw materials that were not available locally could be supplied. Wood ash, clay and bracken were commonly traded; bracken for example, was also used in soap production, as livestock bedding, for thatching, and as a packing material. Accounts dated to 1479 show that ferns were sold to the glasshouse at Wolseley in Staffordshire (Welch, 1997, p. 32). Staffordshire had a local source of refractory clay that could withstand the high temperature of the glassmaking furnaces, whereas the glassmakers in the Weald probably brought in clay since the local Wealden clay, which was not refractory, was unsuitable for making crucibles (Kenyon, 1967, p. 13). Sand could also be supplied. Documentary evidence from the Weald shows that the sand used in glassmaking was quarried from outcrops at Hambledon Common and Broomfield Hanger, a return trip of around one day's cart drive from all of the Wealden furnace sites (Kenyon, 1967, p.35). Although produced during the post-medieval period, Kenyon (1967, p. 35) refers to a map dated to 1629 that highlights the digging and selling of white sand for glassmaking from Lodsworth Common in West Sussex.

Because of the huge amount of timber required to run the furnaces, glassmaking in England and on the continent would transfer to new wooded areas as the woodland was expended. Wedepohl (1997, p. 254) proposes that German furnace sites in the medieval period moved every 5-30 years and documentary evidence from the Weald suggests that this could be as little as 13 months (Kenyon, 1967, p.106). This duration may be based by Kenyon on the 13-month lease that was given to glassmakers in the Weald in 1385 by Seez Abbey in France, the motherhouse of Arundel Priory (Kenyon, 1967, p. 11; Elvins, 1981, p. 1). Kenyon also describes how the lack of surviving furnace structures in the Weald could be explained by the wholesale stripping and relocation of the entire site in '... this stoneless country …' (1967, p.107). Another factor in the location of the glasshouse may have been topography; Winbolt (1933, p. 53) describes furnace sites in the Weald sited at or near hilltops to take advantage of the natural draught.

2.7.1 Forest administration

The pressure on forests from glassmaking and other forest-based industries such as iron smelting and tanning, plus the use of timber for firewood, and house and ship building led to the deforestation of vast areas of woodland in northern Europe. In the 14th century continental forests were administered: in France and Germany for example, a series of regulations to control consumption was introduced (Wedepohl, 2010, p. 66). In England, the timber crisis prompted a number of controlling measures to limit wood consumption, although with minimal effect until the banning of the use of wood as industrial fuel in 1615 (Kenyon, 1967, p. 14). After this time the glassmaking industry in England moved to the coal areas such as the Midlands and the Northeast. After initial difficulties were resolved, coal became a very efficient fuel in glassmaking: to make one tonne of glass required around five or six tonnes of coal as opposed to 150-250 tonnes of wood (Godfrey, 1975, p. 83; Cable, 1998, p. 324).

From the mid-12th century, up to one third of the area of England that included Crown and privately-owned forests, moorland, fields and some villages, was preserved for royal hunting, and protected by the Forest Law (Magraw and Thomure, 2017). The Law was introduced from Normandy after the Norman Conquest and was a separate legal system with its own courts and laws that aimed to preserve these forests for the King's use. The King's rights over 'the vert', the vegetation, for example, forbade the felling of trees in the protected areas with severe penalties for those who committed offences (Hudson, 2012) although Rackham says the more extreme 'Byzantine penalties' were not exacted and were probably more like a fine or perhaps imprisonment (Rackham, 2004, p. 168). The extent of the area under Forest law in the 12th and early 13th century may have limited the choice of potential glassmaking locations in England. In 1217 The Charter of the Forest re-established rights of access to some areas and economic rights were granted, for instance to gather wood for fuel, albeit with limitations to ensure sustainability (Magraw and Thomure, 2017). This is demonstrated through a 14th century rental agreement for William Stapleton of 'le glashous' who was permitted to 'have dead wood at will' from Inglewood Forest in Cumbria, then under Forest Law (Parker, 1909, p.35) (see map below, 2.17).

2.8 The People and the processes

A key source to understand the glassmaking process and the craftsmen involved is the depiction of a Bohemian furnace scene in Sir John Mandeville's Travels, dated to around 1410 (British Library, MS. 24189). This is a miniature showing the multiple operations involved in the production of forest glass and is a good insight into the division of labour in glass production. Ada Polak (1975, p.17) describes the tableau in detail, but essentially the scene shows five furnace workers: a stoker, gatherer, the gaffer, or master glassmaker and an annealer working at the furnace, and an inspector who checks the finished vessels. In the background one worker digs from a pit, interpreted by Polak as collecting the burned ashes although Kenyon describes this as digging for sand (1967, p. 73), while another carries the raw material to the furnace. Polak also describes a glass pedlar taking finished goods off-site, and another pedlar carrying a sack of possible wood ash for sale to the site (figure 2.16).

Wood for fuel was cut at least a year before being used, to be dried. Judging the dryness of the wood, considering the wind strength and direction (using cockle shells suspended from the roof above the furnace as seen in Mandeville's scene), and feeding the fire was a specialist job for the stokers who would have worked night and day sometimes for months at a time (Polak, 1975). Similar attention was required by the annealer for the slow cooling of the finished glass. Judging the temperature of the furnace and annealing oven was a nuanced and skilful procedure undertaken without technical instruments. Experimental research by *The Roman Glassmakers* shows that establishing when the batch was ready for blowing was conducted by gauging the viscosity of the melted glass, and estimating the temperature of the

annealing oven could be achieved by stringing a thread of molten glass across the top of the lehr and observing whether it set or remained soft (Mark Taylor, 2022, in conversation with author, 17 June 2022).

An experienced, well-choreographed team was required for the continuous running of the glasshouse (Smedley, Jackson and Booth, 1998). In the medieval period this may have been small, perhaps two to six people (Polak, 1975, p. 22). Documentary sources such as trade accounts, legal agreements, parish records and wills suggests that this team, both on the continent and in England, was a family unit, or a kinship network (Epstein, 1998, p. 687) that comprised multiple glasshouses run by an extended family. Winbolt (1933, p.11) gives some examples of glassmaking families from the Weald such as Laurence Vitrearius of Chiddingfold and his son William le Verir; John Peytoe who left his glass-working tools to his son John; another Peytowe in 1563 left his tools to his son William, whose own son Roger inherited the family's glassmaking sites. Similarly, families from Staffordshire, such as the Glassmons and the Harveys are found in records (Welch, 1997, p. 4).

Figure 2.16 An illustration of an early 15th century glassmaking furnace taken from the picture book of Sir John Mandeville's Travels (c.1410). (BL, Add. 24189. fo1. 16) Attribution: British Library, CC0, via Wikimedia Common

2.8.1 The family pattern

This family pattern of ownership as seen in glassmaking was not unusual in small scale, rural-based industries, and is also demonstrated through surname evidence in the iron industry, for example see Geddes (1991, p. 186). The pattern enabled the transmission of the glassmaking skills and ensured recipes and techniques were kept secret (Welch, 1997, p. 36). These were probably passed on orally from father to son and memorised. In the 17th century there is evidence that glassmakers recorded their methods and recipes in diaries and inventories using symbols and shorthand (Brain, 2024, p. 118). However, there is no surviving evidence of the use of written symbols in the earlier medieval period. After the invention of printing using movable metal type in the mid-15th century, the technical knowledge and trade secrets of glassmaking were disclosed more widely, although they were probably limited to the middle and upper classes, many of whom could read (Whittock, 2009. 277) (see section 3.7).

2.8.2 Guilds

Merchant and craft guilds that included weavers, painters and candlemakers as well as the glass-painters operated from the 11th century in many towns and cities across Europe including in France, Italy, the Netherlands, and from the 14th century in England. They existed principally to protect the interests of the members and their profession by maintaining standards, govern competition among members, and significantly to run apprenticeship schemes that ensured the transmission of knowledge down the generations. A formal guild apprenticeship led to qualification as a journeyman who was encouraged to leave the workshop to work for a new master in order to learn new ways. In such a manner the diffusion of ideas, 'technological transfer', across geographical space was stimulated (Epstein, 1998, 702).

Glass painting guilds were often city-based and in England there were, for example, glass painting guilds in York, London, Chester and Norwich (Marks, 1993, p. 42). In order to maintain quality of workmanship, the glass-painting guild sometimes used its power to demand the use of the best glass, or at least the best that could be afforded by the client. For instance, in 1470 the glass painter's guild of Antwerp stipulated that alongside locally produced glass, only the higher quality Norman crown glass be used by its members even though it was the most expensive (Caen, 2009, p. 236). Rhenish glass, it is indicated, could be used in the borders of the glazed panels. The guilds were therefore powerful in stipulating the source of the glass in glazing and how the glass from different regional producers was used.

There is very little evidence of glassmakers' guilds in Europe, exceptional cases, both in Italy, are Venice in the 13th century and Altare in the 15th century. In many ways therefore the family unit and kinship network assumed the role of a guild in protecting recipes and techniques, and in training younger generations in the craft through experiential learning. However, in the

static, rural conditions where glassmaking took place without the guild network of journeymen the exchange of ideas was difficult if not resisted (Haskins, 1926).

Surname evidence from the Weald (and also at post-medieval furnaces such as Bolsterstone and Catcliffe in Sheffield) shows continuity in family run workshops with father-son, or father to son-in-law or nephew succession. This may be due to protecting the family or extended family's interests but may also reflect the likely sporadic nature of forest glass production in some areas. It is probable that glassmaking in England was a part time occupation, generally supplementing income through farming (Welch, 1997, p. 36). Court rolls from 1303 show that Wealden glassmaker William le Verrer made a complaint against the Prior of Wenlock for stealing his cows and corn (Ashdown, 1919, p. 17). Whatever the extent of le Verrer's farming enterprise it nonetheless demonstrates the dual employment of some glassmakers. It is known that some glass painters also held additional occupations (Marks, 1993, p. 42).

Glassmaking activity may have been intense for several months, fulfilling orders particularly for larger buildings such as monasteries and chapels, with inactive periods in between commissions: a model that required a flexible workforce. Glassmaking may also have been seasonal because of the availability of raw materials, for instance bracken, which was harvested in the summer months (Merrifield, 1967, p. 212). In a letter to Lord Burghley when applying for a license to make glass in the Weald around 1567, John Carre asserts that 'at certain times of the year as at the height of summer the furnaces will be out for eight or ten weeks during the great heat'. As Kenyon indicates (1967, p. 121) this gives us some idea of the working year but also that the family pattern allowed for the potentially sporadic nature of the business, at least in England. By employing family members, it was perhaps easier to return to the business when demand called. Based on Carré's assertion, it is likely that glasshouses in some areas of the continent were also of a sporadic nature, shutting down during the hotter months, for example in Lorraine, from where the Carré's Huguenot workers emigrated.

2.9 Procurement

Marks (1991, p. 21) discusses that there was a close relationship and often a contract between the glass painters and the patrons, be they architect, donor or abbot. Finished glass was distributed through merchants who acted as middlemen between the glassmakers and the glass painting workshops. Merchants may have been lone carriers, for example William Holmere who transported window glass from the glassmaker John Alemayne of Chiddingfold to St George's Chapel at Windsor in 1351 (Winbolt, 1933, p. 8) or organisations such as the Hanseatic league who controlled the import-export of glass from Germany, the Low Countries and Central Europe. The Hanseatic League traders supplied St George's Chapel, for example, with coloured glass in the mid-14th century (Marks, 1993, p. 30). There were also agents, many

of whom were glassmakers themselves, who acted on behalf of other glassmakers in dealing with the merchants. Records from the 16th century show Isaac Bungar working as both a glassmaker and glass agent, liaising between the Wealden and French glassmakers and a merchant's London warehouse. Bungar was accused of price fixing and controlling the supply of glass from the Weald by the merchants (Clark, 2006, p. 105). On the continent, specialist merchants were also used, for example for the glazing of Abbey of Gercy at Sainte Chapelle in Paris, a commission that was undertaken in just five years (Lagabrielle and Velde, 2005, p. 341).

Accounts from the Weald dated to 1295 indicate the use of a 'glassecaryour' in a conveyance between Thomas Shorter (may be a corruption of Schurterre) and Thomas Ropley (Clark, 2006, p. 126); and another Ropley, Henry, also a glass carrier in the 15th century (Robinson, 1974). Transporting glass from its forest location was laborious, lengthy and expensive (Marks, 1993, p. 50-51). In the transaction between John Alemayne and William Holmere for the transportation of window glass from Chiddingfold to the Royal Palace at Windsor, Willmott (2005, p.45) identifies that up to one sixth of the payment for the glass was for transportation. It is unlikely that there were many woodland tracks suitable for carts, therefore much of the journey would have been by packhorse. This situation looks to have continued in the Weald at least until the early 17th century when glass carrier Henry Strudwick of Kirdford left pack horses in his will of 1614 (Clark, 2006, p.66). On the continent large wagons were used for the long haul to ports, for instance from Lorraine (Rose-Villequey 1971, 189, cited in Clark, 2006, p.127).

River routes where possible would also have been used to carry bigger loads, more quickly with reduced breakages; in Germany for example, the Rhine was the most likely transportation route for the window glass for Cologne Cathedral (Wedepohl, 2010). Other navigable rivers in the German glassmaking areas included the Main, Weser and Elbe. In France, it is probable that traders made use of navigable rivers such as the Seine and the Loire in the north-west and the Meuse and Rhine in the north-east (Barrera and Velde, 1989). In the Weald, access to London was not possible via river as the River Wey, which connected to the Thames was not fully navigable until the 17th century (Kenyon, 1967, p. 112) and thus freight from the Weald to London, its biggest market, may have gone across the country or alternatively via one of the small ports along the south coast, for example Littlehampton. Kenyon (1967, p. 12) proposes the shipping link between Littlehampton and Rouen, for example as a possible route for the pioneering, French émigré glassmakers. Transportation from Staffordshire glassmaking centres may have involved transport along the River Trent (Welch, 1997, p. 35) as it was possible during the medieval period to travel from Stoke-on-Trent to Leicester, Derby, Nottingham and Lincoln (Jones et al., 2017, p. 35) and then via the Humber and Ouse to York.

Many rivers in England were navigable from ports, for example the Ouse, therefore imported glass may have been easier, with fewer breakages and possibly cheaper to acquire than English glass if brought overland. Maritime ports on the continent included Calais, Le Harve, Rouen, Bruges, Utrecht and Hamburg, with access, for example to Southampton, London and Hull. The 15th century Rhenish and Flemish glass came through Hull using the Hanseatic League or York Merchant Adventurers (Marks, 1993, p. 30). Documentary references to the purchase of window glass from the continent include Rouen in Normandy for the glazing of Exeter Cathedral in 1318; glass from Normandy and the Rhineland purchased by glaziers in York in the early 16th century; and window glass from Normandy for the glazing of Coldharbour (London residence of Margaret Beaufort, mother of Henry VIII) in 1485 (Erskine, Raine and 'Med. Glazing Accounts' quoted in Marks, 1991, p. 30-31).

2.9.1 Weights and measures

Glass was packed for transport in cases, or cradles, with bracken, hay and straw as packing. Crown glass exported from Normandy was packed as 24 crowns per cradle (Godfrey, 1975, p. 200). A cradle weighed 120 lbs (Marks, 1993, p. 31). In the 16th century broad glass sheets from Lorraine were packed together in bundles of three sheets or panes and placed in baskets of willow (Rose-Villequey, 1973, p.195; Godfrey, 1975, p. 201; Ladaique, 1973, p.73, cited in Clark, 2006, 125). In England in the 14th and 15th centuries, window glass was sold by the glassmaker to the glass painter by weight in 'weys' (a wey was 5 lbs and a foot of medieval glass weighed approximately half a wey), whereas the glazier was paid for the painted glass by the client by the foot (Marks, 1991, p. 31, 266). The sale from the glassmaker by weight may have related to the production of crown glass, perhaps sold as a whole crown (that measured 0.5 m to >1 m diameter) or as Cooper (cited in Caen, 2009, p. 234) and Winbolt (1933, p. 59-60) suggest, cut into quarries at the glasshouse (above, 2.6.2). Either way the thickness of crown glass varied enormously depending on whether it was cut from the centre or the edge. Crown glass is known to have been manufactured in the Weald and Staffordshire and this is discussed in the following section together with an overview of glassmaking in England.

2.10 Glassmaking in England

There are two known major centres of glass production in England in the medieval period: the Weald on the Surrey-Sussex border where there is archaeological evidence of glassmaking from the 13th to the 17th century, and Staffordshire, which was active from the late 13th/14th century until the mid-16th century (Kenyon, 1967, p. 13, 26; Welch, 1997). There are also individual, short-lived furnaces in several regions of England including the Delamere Forest from around the late 13th century (Patel, 2023, 142) and an attached glasshouse at Salisbury Cathedral in the 15th century (Salzman, 1952, p. 181) (see below, 2.10.7). The following section details glassmaking in the Weald and in Staffordshire (figure 2.17).

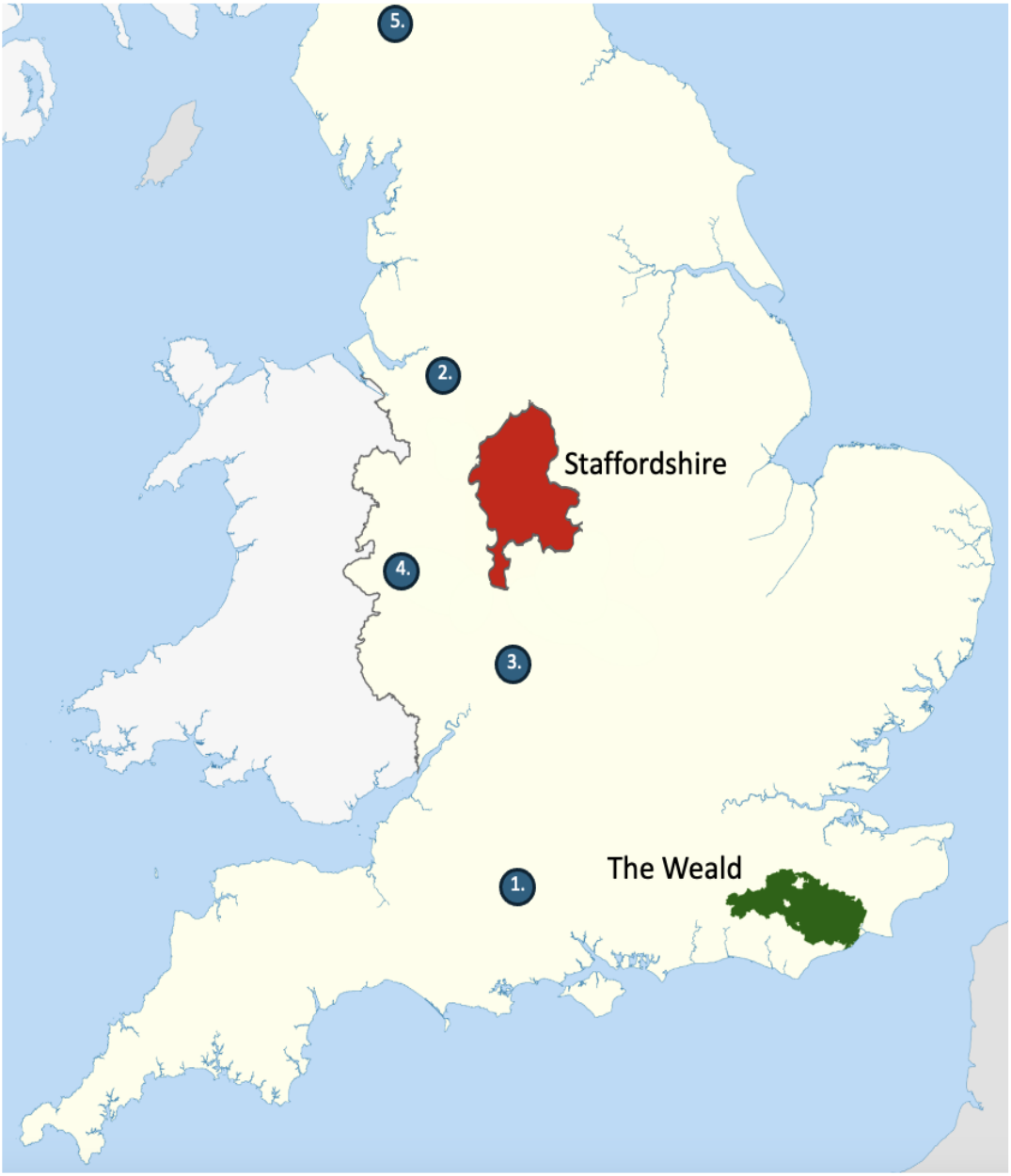


Figure 2.17 Location of the two main medieval glassmaking areas in England, Staffordshire and the Weald, and the short-lived furnace sites, 1, Salisbury; 2, Delamere Forest, Cheshire; 3, Hailes Abbey, Gloucestershire; 4, Shropshire; 5.Inglewood Forest, Cumbria (see section 2.10.7)

2.10.1 The Weald

Much is known about the medieval glassmaking industry in the Weald from written sources and archaeological evidence. In particular, research undertaken in the late 19th to mid-20th century by S.E. Winbolt (1933), G.E. Kenyon, (1967) E.S. Wood (1965) and the Reverend T.S. Cooper (unpublished, see Kenyon, p. 6) whose work was supported by and continued after his death by his daughter, Brenda C. Halahan. More recent excavations have added to our understanding of the industry, for example by the Surrey County Archaeological Unit that runs

the Wealden Glass Industry Project (funded by HE and EH) (2014). Scientific analysis has determined the chemical composition of some of the excavated glasses, for example Welham, 2001, Paynter and Dungworth, 2010, Merchant, 1998 and Meek et al., 2012.

To date, 48 glasshouses have been identified in the Weald in an area of approximately 100 square miles. This area includes the villages of Chiddingfold, Kirdford and Hambledon, which were three of the main glassmaking centres (Kenyon, 1967, p. 13; Crossley, 1994, p. 64) (marked on figure 2.18). Vessels are known to have been produced in these centres as well as crown and broad window glass (Kenyon, 1967, p. 86).

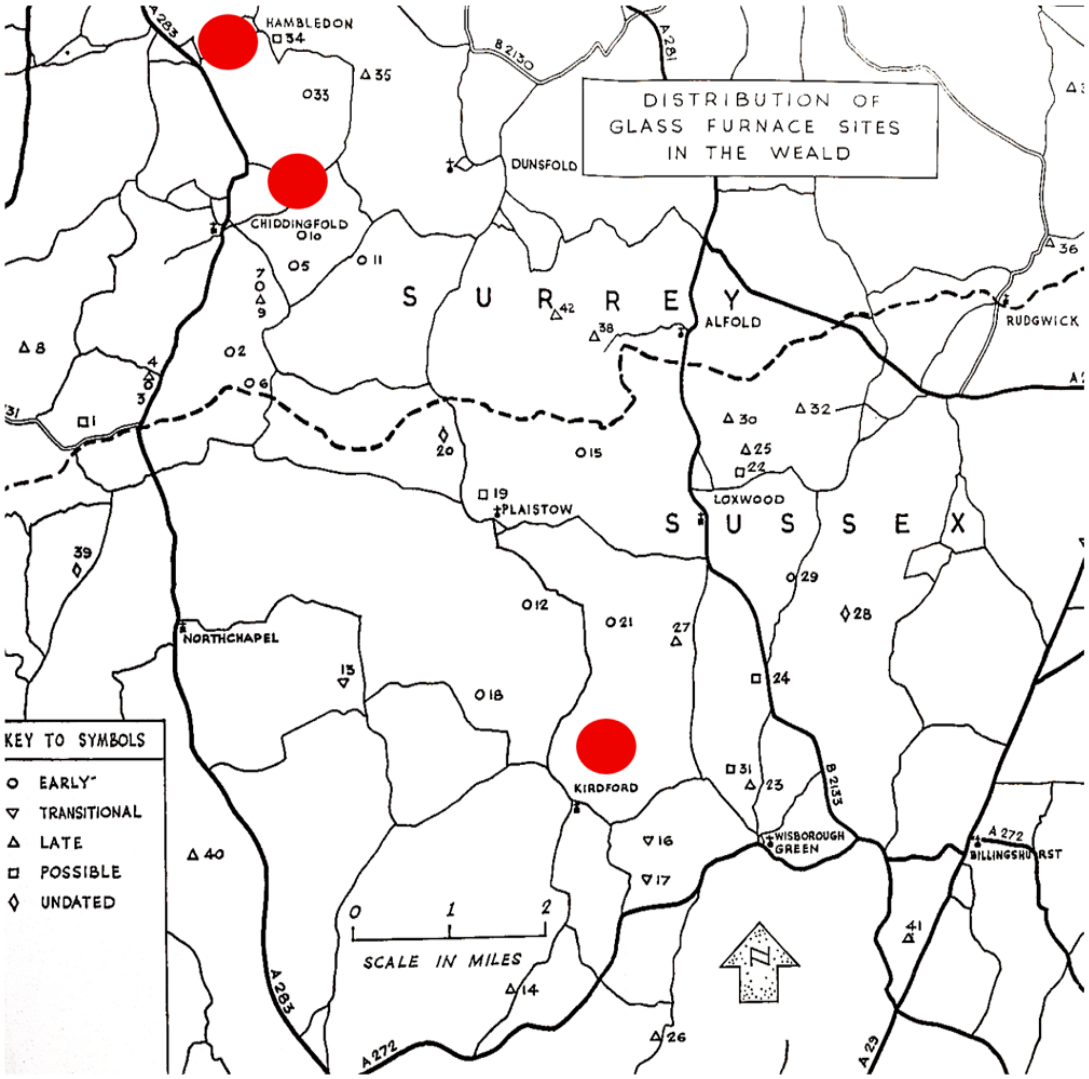


Figure 2.18 Map of the Weald showing the main glassmaking centre, Chiddingfold, Hambledon and Kirdford, taken from Kenyon (1967) back matter

The first known mention of a possible glassmaker is a deed dated to sometime just before 1240 that granted 20 acres of land near Chiddingfold to Laurence Vitrearius (or Vitrarius) (Halahan 1924, p. 77). Winbolt (1933, p. 7) accept the rental agreement as evidence of glassmaking activity, and Kenyon (1967, p. 26) concedes that it 'probably indicates some glassmaking activity here [the Weald] in the first half of the 13th century'. It is recorded that in 1240 Vitrearius provided 'glass, both white' (naturally coloured) and coloured' for Westminster Abbey (Halahan, 1925, p. 77); although there is no evidence of coloured glass production at this time (Marks, 1993, p. 30) and this could be interpreted as the carriage of glass rather than the production.

Winbolt (1933, p.7) refers to the Wealden glassmakers from the 13th century as originating from Normandy and there are several references in local deeds and manorial rolls to glassmakers of French origin, for example John Schurterre, one of the most prominent glassmakers, who in 1343 ran multiple furnaces at Chiddingfold and Kirdford. At least three generations of the Schurterre family made glass in the Weald and it is probable that Peter Shortere, who supplied five 'lodes' of glass to Westminster in 1400 was a family member (Kenyon, 1967, p. 29) (a lode was 200 cradles/cases/seams, totalling 1200 lbs). The French connection is reinforced by the fact that many of the names of the tools and processes used in glassmaking are French (see glossary).

2.10.2 Furnace evidence

The few furnace sites that have been fully excavated in the Weald include Vann Copse in 1931, Fernfold in 1934, Blunden's Wood in 1960 and Knighton's in 1965. The earliest furnace evidence is from Blunden's Wood at Hambledon, dated by archaeomagnetic dating to around 1330 (E. S. Wood, 1965, p. 78), although associated pottery evidence points to a later date in the second half of the 14th century (Willmott, 2005, p. 52). Four hundred fragments of window and vessel glass of medium blue-green colour, 11 samples of working waste, and five samples of cullet were retrieved (Dungworth and Paynter, 2010, p. 1). There is evidence of three or four furnaces at Knightons, which is one of the latest sites and is dated through archaeometric and finds evidence to the mid-16th century. Furnace number four was dual-chambered and the second chamber has been interpreted as an annealing oven (Crossley, 1990, p. 228; Merchant, 1998, p. 86). Crown window glass, bull's eye off-cuts from the crowns and vessel fragments of medium green colour were retrieved along with cullet, showing that window and vessel glass was made at this site. The date of this furnace coincides with the arrival of immigrant glassmakers to the Weald from the continent, and a change in the glass type to an HLLA composition (Meek, 2011, p. 47).

2.10.3 Glassmaking in the Weald in the C16 and Jean Carré

Kenyon (1967, p. 13) claims that only two glasshouses were operating in the Weald by the mid-16th century despite rising demand in the domestic market, and details in the parish

registers show that former glassmakers were now listed as yeomen. Reference to the small-scale nature of glassmaking in England is made in a poem published in 1557 in of 'Breviary of Philosophy' by the poet Charnock (Sydney-Lewis, 1916, p. 35) that includes the verse:

'As for glassemakers, they be scant in this land,
Yet one there is as I doe understand:
And in Sussex is his habitacion,
At Chiddensfold he workes of his occupation'

The shortage of skilled glassmakers was addressed in 1567 through the recruitment of French-Huguenot glassmakers by Jean Carre´, a glassmaker and entrepreneur who established glasshouses in the Weald and in London (Kenyon, 1967, p. 13). Glass with an HLLA composition, which had been used on the continent since around 1400, was now made for the first time in England allowing cheap, high quality window glass to be produced in what Kenyon describes as a technical renaissance (Kenyon, 1967, p. 14; Crossley, 1972, p. 423; Mortimer (in Welch), 1997, p. 39; Wedepohl and Simon, 2010) (see section 2.3.5 above). Until this time all English glass had a potassium-rich forest composition. By the early 17th century Norden's Surveyors Dialogue records only 'three or four glasshouses' in operation in the Weald, as opposed to the 140 'iron hammers and furnaces' (Norden, 1610, p. 215). In 1615 the use of wood for industrial fuel was banned by James I (Meek, Henderson and Evans, 2012, p. 788) and new glasshouses were established in the coal producing areas such as Nottingham, with some of the French Wealden glassworkers relocating with them (Merchant, 1998, p. 57). Glassmaking in the Weald had ended by 1618 (Kenyon, 1967, p. 16).

2.10.4 Staffordshire

There were three known concentrations of medieval glassmaking in the area between the Forest of Needwood and Cannock Chase in Staffordshire, close to the River Trent: two concentrations were near to Abbots Bromley that included Bagot's Park, and another concentration was at Wolseley near the town of Rugeley that included the Little Birches production site (figure 2.19). Placename evidence, deeds, rental agreements and archaeological evidence show that a Staffordshire glass industry was likely to be operating by the late-13th/early-14th century until the end of the 16th century (Welch, 1997, p. 2). Thirty-three furnace sites have been identified (Historic England, 2018, p. 4) and several have been excavated, including Bagot's Park and Little Birches (marked on figure 2.19). Scientific analysis of excavated material to determine the chemical composition has been undertaken, for example Crossley, 1967; Mortimer (in Welch), 1997; Paynter (in preparation), and a chemical and isotopic analysis by Meek et al., 2012.

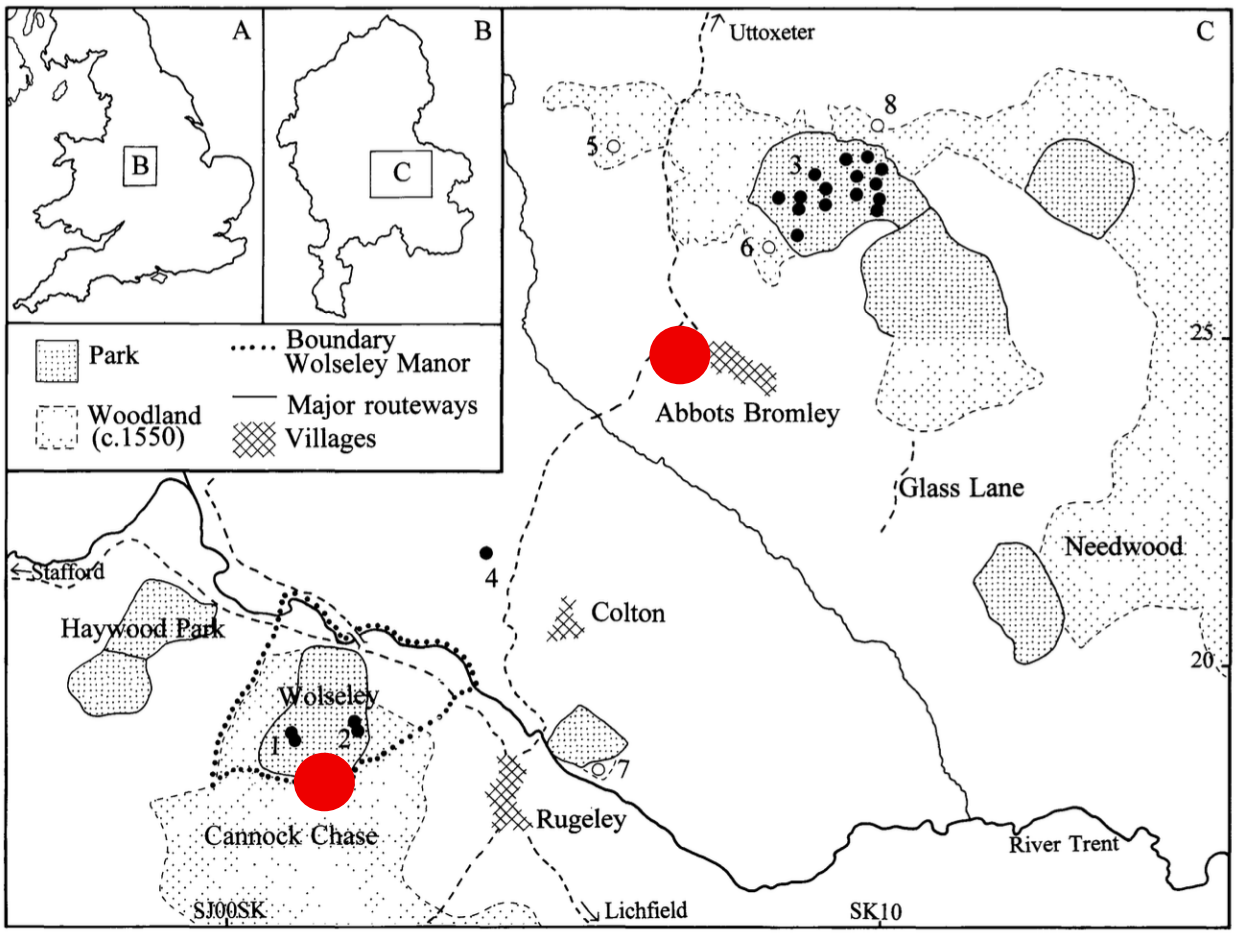


Figure 2.19 Map of glassmaking centres at Abbots Bromley and Wolseley in Staffordshire, taken from Welch, 1997, p. 3

The first link to the glass industry in Staffordshire is a record of 'le glaslone' (Glass Lane) in Bromley Hurst, near to Bagot's Park in 1289 (Crossley, 1967, p. 45). A further record mentions Richard and Thomas le Glasmon in 1327 and a Simon le Glasemon in the same area in 1332 (Welch, 1997, p. 2). A deed dated to 1501 grants land to Thomas Harvey at Bagot's Park and a contract dated to 1585 shows that some members of the Henzey family, who were immigrant glassmakers from Lorraine originally working in the Weald, were now glassmaking at Bagot's Park (Crossley, 1967, p. 47). Archaeomagnetic dating of 22 sites in and around Bagot's Park shows that there were three phases of glassmaking activity: an early site, in use until around 1300; sites running from the late 14th to the mid-16th century; and sites operating from the late 16th to the early 17th century (Meek, 2011, p. 58).

There are several mentions of glassmakers from the Wolseley estate in the written records including: Ralph Glasmon who appears in court records in 1377, and again in 1408 alongside William Glasemon; a John Glasman, who in 1418-19 supplied York Minster with window glass; a rental agreement to site a glasshouse in 1478 and a sales record for the sale of 'ferne' for five shillings in 1479 (Welch, 1997, p. 2).

2.10.5 Furnace evidence

Fifteen furnaces have been located at Bagot's Park in an area of around 1.5 square miles. Site four was excavated in 1966 with finds of crown glass fragments and bull's eyes of a medium green colour. In addition, a possible annealing oven was found relating to vessel production. The site is dated to the first half of the 16th century (Crossley, 1967, p. 45).

Little Birches is one of the better-known furnace sites in Wolseley due to an extensive excavation in 1991/2 (Welch, 1997, p. 6). Two phases of operation were revealed: a north site dated to the 13th/14th century, and a south site dated to the mid-16th century where 35Kg of blown, mostly crown window glass was found - naturally coloured, very light green (Meek, 2011, p. 47). A further five furnace sites producing crown window glass and vessels were nearby and dated through archaeological and documentary evidence to the 14th to 16th centuries (Welch, 1997, p. 29). Production in the 16th century at both Little Birches south and Bagot's Park demonstrate 'a reasonably buoyant market' in Staffordshire at this time (Welch, 1997, p. 35). Glass excavated from both Little Birches and Bagot's Park includes crown glass fragments, which average 3.48 mm thick and are of a pale green colour, from crowns that Welch estimates to have been 700-830 mm diameter (Welch, 1997, p. 19).

2.10.6 The glass goods made in the Weald and Staffordshire

As shown in table 2.3 both vessel and window glass was produced at the Wealden and Staffordshire sites. Kenyon (1967, p. 90) suggests that vessel production was undertaken at the majority of the medieval glasshouses in the Weald and describes the earlier vessels (pre-Jean Carré in 1567) as crude in appearance. In Staffordshire, both glass types were produced at least in the mid-16th century at Bagot's Park and Little Birches.

Table 2.3 Summary of glass production types from Wealden and Staffordshire glassmaking sites from the mid-14th century to the mid-16th century

Furnace site	Glassmaking region	Date	Product	Info.	Reference
Blunden's Wood	The Weald	Mid C14	Vessel and window, possibly crown	Cullet	(Wood, 1965, p. 65)
Knighton's	The Weald	c. 1550	Vessel and crown window	Cullet	(Wood, 1982, p. 19)
Little Birches North site	Staffordshire	C13/14	Window		Mortimer in Welch, 1997, p. 42; Paynter (in preparation)
Bagot's Park	Staffordshire	C14	Unknown		Paynter (in preparation)
Bagot's Park	Staffordshire	Mid C16	Vessel and crown window		Willmott, 2005, p. 69
Little Birches South site	Staffordshire	Mid C16	Crown window and vessel	Cullet	Welch, 1997, p. 18

2.10.7 Short-lived furnace sites

There were several smaller and shorter-lived glassmaking sites, some of which are associated with individual ecclesiastical projects in England (see figure 2.17). These include a glasshouse established in the 15th century to make the window glass for Salisbury Cathedral (highlighted 1 on map, figure 2.17) (Salzman, 1952). Here, purchase records showing the ordering of large quantities of sand are interpreted by Willmott (2005, p. 47) as evidence of primary glassmaking. A glasshouse in the Delamere Forest in Cheshire provided the nearby Cistercian abbey of Vale Royal with window glass between 1280 and 1309 (2 on map, figure 2.17). Here, documentary evidence in the form of Close Rolls (documents issued by the Crown) show that ferns were used for the making of the glass (as opposed to, for example packing material) (Patel, 2023). Marks (1988, p. 217) describes the Delaware glasshouse as a commercial venture since there are references to glassmaking later on in 1309, 1348 and 1357 (Brownbill, 1914, p. 24). The glasshouse attached to Hailes Abbey (3 on map, figure 2.17) in Gloucestershire was another commercial glasshouse, which was in existence at the Dissolution (Marks, 1988, p. 217); and at Inglewood Forest in Cumbria (5 on map, figure 2.17) a 'glashous' was operating in 1316-17 and 1330-31 (Parker, 1909, p. 35; Historic England, 2018, p. 5), and which Welch (1997, p. 2) refers to as an industry.

There is documentary evidence of glass being supplied from Shropshire for the glazing of St Stephen's Chapel at Westminster (Willmott, 2005, p. 46) that suggest that there may have been a glassmaking industry here (4 on map, figure 2.17); until the 12th century, one third of Shropshire was wooded and until around 1300 was under Forest Law. In the same way that the Weald was attractive to high temperature industries that used wood for fuel so there is evidence of iron making here, for example in the 13th and 14th centuries around Chorley, close to Stourbridge, west of Birmingham.

2.10.8 Quality of English glass

Crossley (1990, p. 226) states that in the Middle Ages English producers 'occupied a position at the lower end of the price and quality range', and Kenyon refers to the crude forest wares of the Wealden industry (1967, p. 13). English glass was cheaper than the continental glass and there was no coloured glass production (Marks, 1993, p. 30, 31, 165). The poor reputation of English glass in the 15th and 16th centuries is evidenced in contracts asserting that English glass was not to be used, for example, in the glazing of Beauchamp Chapel in Warwickshire in 1447 (Ashdown, 1919, p. 11), and a reference to the clumsiness of the English glassmakers is provided in a letter to the Secretary of State in the mid-16th century. Nonetheless, there is documentary and compositional evidence, albeit scant, for the use of English window glass in the medieval period.

Kenyon reports that the first conclusive evidence of window glass making in England dates to 1351 when glass from Chiddingfold in the Weald was supplied for the glazing of two royal chapels at Windsor and Westminster (1967, p. 27). Prior to this is a reference to a Laurence Vitrarius renting land in the Weald around 1220/30 (Halahan, 1924, p.7). In 1485 purchase accounts show that English glass (as well as German and Venetian) was supplied for the glazing of the royal residence of Coldharbour in London, and in 1490, John Glasman from Staffordshire supplied the glass for the Holy Trinity church in Tattershall, Lincolnshire. Compositional results from the analysis of glass from Eynsham Abbey, York Minster (Great East Window) and New College, Oxford have been cross-matched with regional data from Staffordshire to assign a provenance (albeit tentative at Eynsham and New College). Indirect evidence suggests English glass was used at Gloucester Cathedral, where Knowles (1922, p. 152) speculates that the large areas of colourless glass are English since continental glass was unavailable during and soon after the Black Death because ships from abroad were banned from docking at Bristol. English glass, on the other hand, was available during this period. The composition of glass produced in England is discussed in the following section 2.9.

Table 2.4 summarises the evidence for the use of English window glass (highlighted in green) and table 2.5 summarises the reference to the poor quality or inadequacy of English window glass (highlighted in red).

Table 2.4 Summary table of documentary and archaeological evidence of the use of English window glass

Date	Consumption site	Production area	Information	Reference
1220/30	Probable glassmaking evidence	The Weald	Land rented to Laurence Vitrarius (LV)	(Halahan, 1924, p. 77)
1240	Westminster Abbey (WA)	The Weald	Records at WA show LV providing glass (including coloured). Possibly also at Salisbury Cathedral at a similar time - comparison by eye	(Halahan, 1924, p. 77) Winbolt, 1933, p. 7
1351	St George's Chapel, Windsor and St Stephens	The Weald and Staffordshire	Period of the Black death	Ashdown, 1919, p. 26 Kenyon, 1967, p. 27
Mid C14	Eynsham Abbey	Cross-matched with Little Birches, Staffordshire	Tentatively English	Paynter and Doonan, 2002
1360s	Gloucester Cathedral	Knowles supposes the colourless glass is English	Limited coloured glass availability from the continent	John Knowles, 1920s, p. 352
1385	New College Chapel, Oxford	Possibly English on composition, painted by Thomas Glazier	Use of English glass because of French hiatus	Adlington et al., p. 10
1390s	Winchester	Thomas Glazier painted and possibly also sourced English glass as New College		Adlington et al., p. 10
1400	Westminster	Probably the Weald	5 lodes supplied by Peter Shortere	Kenyon, 1967, p. 29
1405-08	York Minster	Staffordshire	Painted by John Thornton using colourless English glass	Freestone et al., 2010
1418/19	York Minster	Staffordshire	Supplied by John Glasman	Welch, 1997, p. 35
1480	Church in Tattershall, Lincolnshire	Staffordshire		(Welch, 1997, p. 35, 37
1485	Coldharbour, London	English	Sourced Norman, Rhenish, Venetian and English glass	Woodforde, 1950, p. 74-127, Marks, 1993, p. 31

Table 2.5 Summary table of documentary evidence showing the poor reputation of English window glass

Date	Consumption site	Production area	Information	Reference
1447	Beauchamp Chapel, Warwick		Contract stated English glass not to be used, otherwise penalties	Ashdown, 1919, p. 11
1449	Contract for John Utyman to make coloured glass and teach English glassmakers since 'the said art has never been used in England'			'indifferent quality', Marks, p. 30 'crude', Kenyon, 1967, p. 13
1565	Letter to Secretary of State		Reference to the clumsiness of English glassmakers	Ashdown, 1919, p. 12

2.11 Regional compositions

Many studies have been undertaken on the chemical composition of excavated medieval glass that includes window and vessel glass fragments from production and consumption sites, and working waste such as drips, moils and crucible glass residue from production sites. This data can be used to illuminate regional compositions and techniques and their development over time.

The regional data is also used in this research to assign provenance, where possible, to the monastic window glass.

2.11.1 Selection of regional data

The regional studies used in this project encompass 24 different glass compositions from sites in England, France, Germany and Central Europe (Bohemia) (see figure 2.20). The studies have been chosen to represent regional production areas from where it is known that glass consumed in England was sourced. A summary of data in terms of selection is as follows:

- The data used is from glasses that are dated between the 12th and 16th centuries
- Typical compositions of the glass deriving from the sites are used
- Published averages are used only if the full data set is not available and standard deviations are low, suggesting a tight compositional group (see Wedepohl, Simon and Kronz, 2011, p. 93)

- The same range of major elements is selected that are reported in both the regional data and the study data
- The data is accurate and precise according to pre-defined standards
- Where there are duplicate studies the data with the lowest limits of detection and most accurate standards data are used

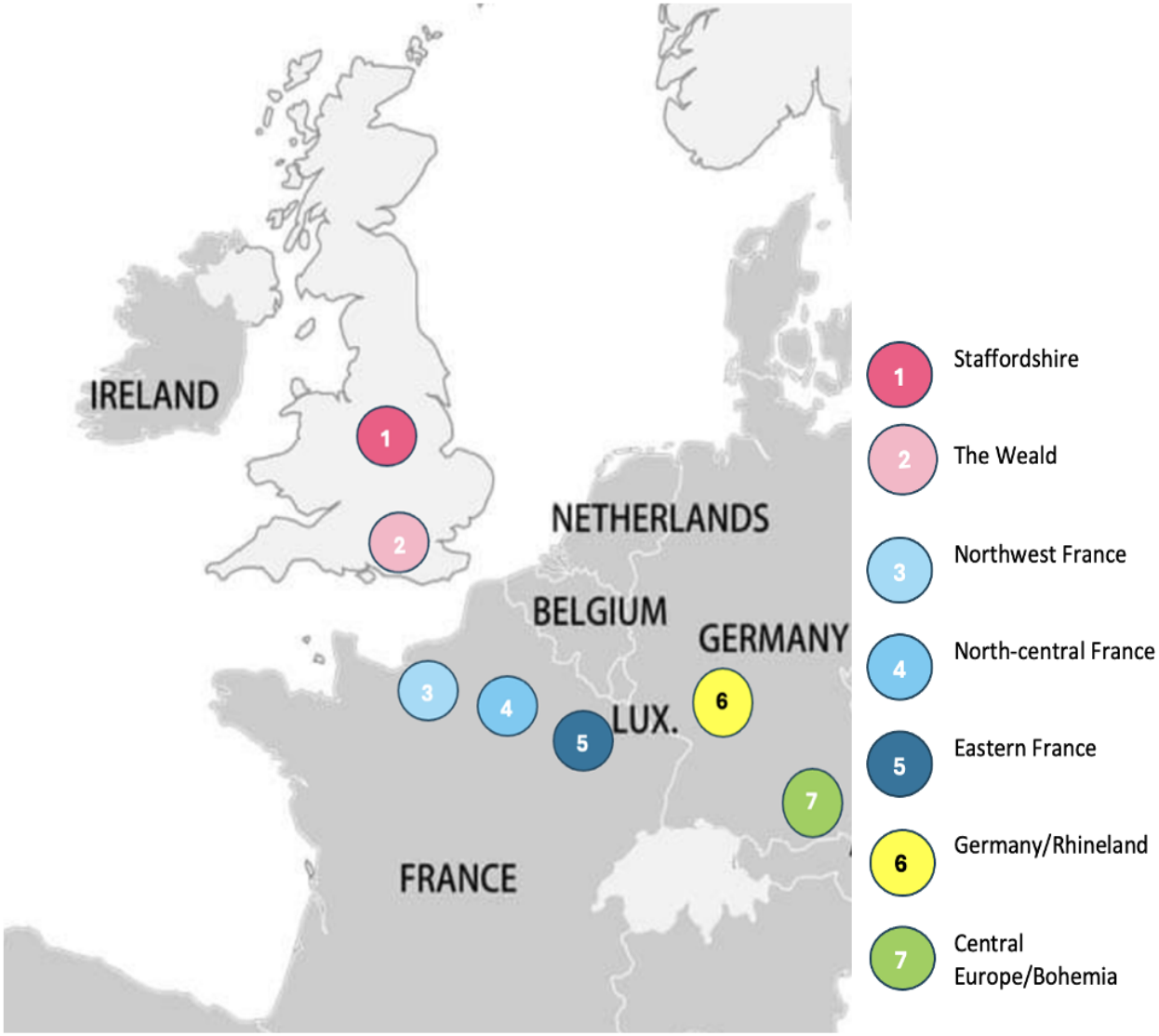


Figure 2.20 Map showing the main glassmaking regions in Staffordshire, the Weald, northwest France, north-central France, eastern France, Germany (Rhineland) and Central Europe (Bohemia). Regional compositional data is used in this research to assign provenance, where possible, to the monastic window glass

2.11.2 Regional consumption sites: assumed local

Excavated window glasses from consumption sites on the continent are generally assumed by the authors to be of local production. This is due to the large number of glasshouses in some areas of continental Europe, for example there were 40 glasshouses working in Germany in the medieval period (Wedepohl, 1997, p. 253), and procurement from a local source reduced

transport costs and breakage that might have occurred during a longer haul. Some consumption studies show the use of multiple sources when local production could not meet the demands of a large glazing campaign, for example at St. Chapelle on the Ile de Paris (see 4 above on map) (Lagabrielle and Velde, 2005), or where particular coloured glass was required, for example Saint-Jean-des-Vignes Cathedral in Soissons in the north-east of France (Brill and Pongracz, 2004). It is possible that vessel glass, particularly common forms, had a local market and were produced locally. The data from consumption studies of vessels has therefore been included for cross-matching but provenance remains tentative.

The following is an overview of the regional compositional studies for northern Europe used to assign provenance, where possible for the glasses in this study. A tabulated summary of the regional compositions used in this study are shown in table 2.6 at the end of this chapter, section, 2.16.

2.12 France

Glasshouses in parts of Europe including France had continued to work pre-formed, secondary glass in the post Roman period and thus the craft tradition, knowledge and skills of glass working may have been maintained into the medieval period (Wedepohl, 2010, p. 63). The French glassmaking industry and the production of window glass from primary glass was precipitated by the demands of the new Gothic architecture with larger windows requiring more glass than the previous Romanesque style (see section 3.8.4). The first Gothic cathedral was St Denis in Paris, consecrated in 1144. France has the largest corpus of extant medieval windows and excavated window glass in Europe dating from the 12th century that includes the glazing of St Denis and an extensive collection of excavated 11th-15th century window glass housed in the Cluny Museum that includes, for example, St Chapelle and Gercy Abbey (Lagabrielle and Velde, 2005, p. 341). Much of the compositional data is derived from the analysis of glass from consumption sites, and some of the sample glasses used for provenance in this PhD study are housed in the Cluny collection. The French regional studies used to provenance the research material in this Doctoral study are as follows:

Barrera and Velde (1989) collected and compared data from 81 samples of excavated vessel fragments from mostly urban or peri-urban sites in the northwest and north-central France and working waste from glassmaking sites in eastern France. These sites are:

- Glassmaking sites at Argonne, Pairu and Bercettes (eastern regions)
- Consumption sites at Cour Napoleon, Louvre , St Chapelle (north-central); Rouen, (northwest); Angers/Loire; Metz, Lorraine (eastern regions)

Gratuze, unpublished (although the data may be in individual site reports; date of analysis shown). Data are from 92 fragments of window glass from consumption sites in the north-central, northwest and western regions of France, dated 13th-15th century. These sites are:

- Northwest: Rouen
- North-central: central Paris - St Chapelle, St Denis and Isle de France, Abbeye de Jarcy (Gercy)
- Western: Maillezais, Suscinio Castle, Brain/ Alonne

2.12.1 Composition of French glass

There are significant compositional differences in medieval French glass according to geographical area: in the south of France, medieval glasses are characterised by high sodium (14-20%) and low magnesium and potassium (<2%) due to the use of halophytic plant ash in the recipe, 'the Mediterranean tradition' (Velde and Barrera, 1986, p. 93); in northern France, potassium-rich forest glass was produced. The main furnace sites for the production of forest glass were located in:

- Normandy in the northwest, particularly in the Lyon Forest region and in Brittany (Sterpenich and Libourel, 2001)
- North-central area around Paris
- Lorraine in the Argonne Forest in the east

2.12.1.1 Northwest France

There is archaeological and documentary evidence that window glass using the crown method was manufactured in Normandy from the 13th century (Lagabrielle and Velde, 2005, p. 341). Normandy forest glass dated to the 13th and 14th is characterised by a high magnesium (>5.2%), phosphorus (≤5%) and sodium (>2%) content with a Ca:K ratio of <1.5 (Velde and Barrera, 1986). In the 15th century the Ca:K ratio remains the same demonstrating that the HLLA recipe was not yet adopted, but the composition is higher in silica (55-63%) and contains high levels of sodium (>2%), which is attributed to the addition of salt (NaCl) to the recipe (Velde and Barrera, 1986; Lagabrielle and Velde (2005, p. 341). Glass from Brittany has high levels of magnesium (up to around 8%), and also sodium (>3%), which is again attributed to the addition of salt, possibly in the form of evaporated brine (Sherborne, 1971, p. 8). There were ports around the Brittany coastline and in the medieval period Rouen in Normandy was a port city - although around 65 miles from the northern coast of France, it was connected via the River Seine to the port of Le Harve and the English Channel (Pounds, 1947, p. 221).

2.12.1.2 Eastern France

From the 13th century window glass was produced in the eastern region of France: there is evidence of 14 glasshouses located in Argonne region, west of River Meuse dated to the 13th to 15th centuries, and at Perupt, dated to the 13th century (Foy and Sennequier 1989, 67-69). In the 15th century there were 44 glasshouses in Lorraine, and was thus a significant industry supplying the local, national and international market (Tyzack, 1998). Window glass produced

predominantly using the broad technique was exported to England. Eastern France was connected to the northern French ports using the river network that included the rivers Meuse, Marne, Oise and Seine (Crone, 1941, p. 36).

Forest glass was produced from the 13th to the early 15th centuries with low levels of sodium (<1%), manganese (<0.8%) and magnesium (<3.5%) and a high level of calcium (>18%), which increased over time (Barrera and Velde, 1989, p. 92), and the HLLA recipe was used from the early 15th century. In the mid-16th century glassmakers from the eastern region moved to the Weald and made broad glass using the HLLA recipe, see above section 2.10.3.

2.12.1.3North-central France

In the medieval period there were huge glazing projects undertaken particularly around Paris in the central northern area of France, which included the cathedrals of St Chapelle and St Denis. For these two glazing projects window glass was sourced both from local producers and those further afield because of the huge scale of the projects and the short timeframe demanded by the patrons for the completion of the building work (Hunault *et al.*, 2021). St Chapelle for example was completed in less than seven years. In the medieval period this region was connected to Paris using the river network that included the River Meuse, and from Paris along the River Seine to the northwestern glassmaking areas and the northern port of Le Harve. Glass for the English market was shipped from here and other ports along the northern French coastline to the English ports. The composition of glass from the north-central area, much of it crown glass, is similar to that of Normandy but with a lower sodium content (around 0.8%) (Barrera and Velde 1989, p. 93; Lagabrielle and Velde, 2005, p. 341).

2.13 Germany

Furnace sites producing window glass from raw materials were located throughout Germany in the Lower Saxony Hills in the north, east of the Rhine in central Germany and in the Black Forest in the south-west of Germany. The main concentration was in the mountainous forests in an area to the east of the Rhine in the central area (Wedepohl and Simon, 2010) and the earliest evidence of window glass production is at Bursfelde Monastery in the Bramwald Mountains in the Rhine area where a glasshouse operated between around 1200 and 1240 (Wedepohl, 2000). Wedepohl, (1997, p. 253, 246) describes an increase in glass use in Germany from around 1250 with the founding of new towns with cathedrals and churches, for example Cologne Cathedral (c. 1260) and Altenberg Cathedral (c. 1270), and estimates that there were 40 glasshouses operating in Germany during the late medieval period.

The river system, notably the Rhine but also other navigable rivers such as the Ems, Wesser and the Elbe enabled the glasshouses to supply the internal market and also reach the ports on the northern coast for the export market to England (Crone, 1939, p. 334). The Hanseatic

League, which operated from the 12th century facilitated the export of window glass to east coast ports in England using ports such as Hamburg and Bremen (Spicer, 2017, p. 1007).

Compositional data from 45 excavated glass samples from two research projects are used in this PhD study to assign tentative provenance. These are detailed as follows:

1. Wedepohl, 1997: data from 29 samples of excavated window glass from urban and monastic sites and working waste from a glasshouse in the Rhine-Meuse area (Corvey, Steim/Bramwald Mountains and Hoxter) dating from the 13th to 15th centuries

2. Wedepohl, 1996: data from 16 excavated samples from a glasshouse in the Rhine-Meuse area (Spessart), and also from latrines in Mainz provenanced to the Spessart glasshouse. All sample glasses are dated to around 1300

2.13.1 Composition of German glass

Two distinct compositions of glass were produced in Germany. Until around 1400, forest glass was produced with a high level of potassium (>18%) and calcium (>20%), and low levels of sodium (<0.3%), with a Ca:K ratio of around 1.2 (Wedepohl, 1997). The composition was gradually replaced with an HLLA recipe that had high calcium (around 24%) but a much lower potassium (<6%) content, with a Ca:K ratio above 4. Salt (NaCl) is thought to have been added to the starting mixture to improve fluidity and refine the glass by removing air bubbles (Gerth et al., 1998; Kawaguchi, 2016). Figure 2.21 is a scatterplot showing the positive correlation of sodium and chlorine that suggests salt (NaCl) may have been used in the production of the sample glasses from Wedepohl's 1997 study, where the R value of the slope is 0.4337 suggesting a moderately positive correlation.

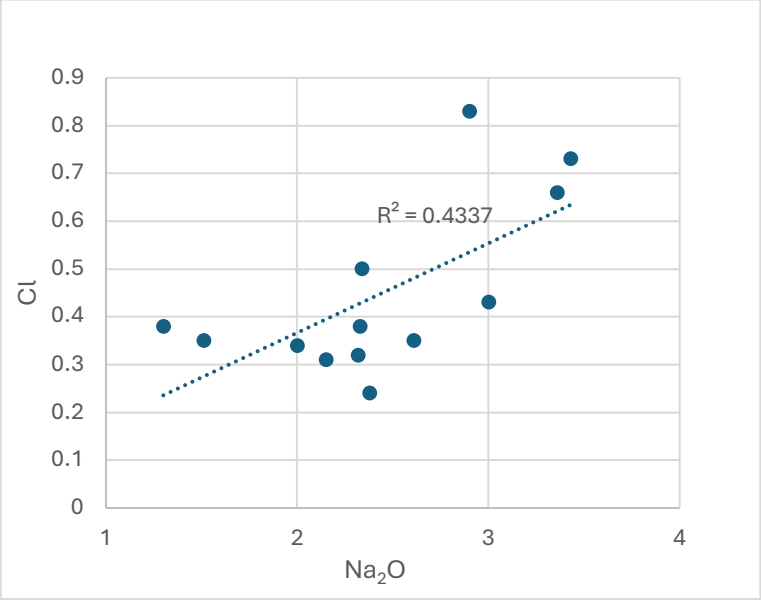


Figure 2.21 Scatterplot showing the positive correlation of sodium vs. chlorine that Wedepohl (1997) suggests indicates added salt (NaCl)

2.14 Central Europe/Bohemia

Glassmaking was undertaken in the Bohemian Forest, spanning the German-Czechia border, and the Ore Mountains in the south of Germany bordering Austria (Cílová *et al.*, 2015). German glassmakers are known to have migrated into Czechia during the 13th century and the earliest evidence of Bohemian glassmaking that dates to the second half of the 13th century is in the north-western part of the county (Cílová et al., 2015). Sir John Mandeville's depiction of a glassmaking site that is dated to around 1420 is a well-known representation of forest glass production in Bohemia, see section 2.8 above.

The data for Central Europe is limited to three studies with 18 samples of window glass, tesserae and working waste from a glasshouse in Moldova, summarised as follows:

1. Wedepohl, 1997, five glass fragments were excavated at Corvey in Germany but it is suggested here to have been imported from Central Europe because their composition is similar to the glass from the Moldovan glassworks with high potassium and calcium, and low levels of sodium, silica and phosphorus (see below, 2.14.1)

2. Cilova et al., 2015, five excavated window glass fragments from West Czechia and Prague dated to the 14th and 14th/15th centuries

3. Cilova and Woitsch, 2012, eight samples of excavated working waste from Bohemian/Moldovan medieval glassworks (Most and Olomouc) dated to the 14th/ 15th and the 15th centuries

2.14.1 Composition of glass from Central Europe

The compositions of the sample glasses from central Europe, above, are characterised by very high potassium levels (>22%) and high calcium (>17%), low sodium (around 0.3%) and a Ca:K ratio <1 (Cilova *et al.*, 2015).

2.15 English production sites

Presented here are the details of analytical studies of glass from the two main areas of glassmaking in England, the Weald and Staffordshire. The background history to English glass production is discussed above in section 2.10.

2.15.1 Composition of English glass

The English composition is characterised by high levels of magnesium (6-8%), moderate to low amounts of potassium (generally <14%) and calcium (generally <15%), and a moderate-high

amount of manganese (0.8-1.5 %) and sodium (around 2%) (see e.g. Meek, 2011). This is similar to the Normandy composition (Lagabrielle and Velde, 2005, p. 342-345), but with slightly lower amounts of potassium, calcium and aluminium (at least for Staffordshire). The English glasshouses did not adopt the HLLA recipe until the 16th century when a new wave of immigrant glassmakers were recruited (see above section 2.9.3).

The regional data shows that there are small compositional differences between Wealden and Staffordshire glass with the latter containing higher levels of manganese (average 1.5% compared with 1.1% from the Weald), and aluminium (1.7% compared with 0.9%), and lower levels of iron (0.6% compared with 0.7%). Meek (2011) and Meek et al. (2012) were able to distinguish between glasses made in the Weald and Staffordshire using isotopic analysis, although there are no recognisable furnace site-specific compositions. The studies found that strontium found in the local soil and sand was the best discriminator.

2.15.1.1 The Weald

The earliest furnace evidence from the Weald is Blunden's Wood at Hambledon, dated to the second half of the 14th century (Willmott, 2005, p. 52). The site was excavated in 1960 and around 400 fragments of window glass, vessel glass and cullet were retrieved (Dungworth and Paynter, 2010).

Compositional data from the following research is used in this study to assign provenance, where possible; all of the Wealden glasses are dated to the 14th century.

- Meek, 2012: 19 samples of working waste
- Dungworth and Paynter, 2010: 12 samples of vessel glass and working waste
- Merchant, 1998: six fragments of working waste and glass
- Welham, 2001: six samples of working waste and glass

2.15.1.2 Staffordshire

The earliest furnace evidence from Staffordshire is Little Birches at Wolseley, dated to the 13th/14th century. The site was located in 1990 and excavated in 1991/2. Crown window glass, working waste, and coloured and uncoloured cullet were retrieved (Welch, 1997, p. 6, 18-25).

Compositional data from the following research is used in this study to assign provenance, where possible:

- Mortimer (Welch, 1997): three samples from Little Birches north site dated 13th/14th century
- Paynter (in preparation): two samples from Little Birches dated to the 13th/14th century (based on compositional similarity with Mortimer's sample, above); nine samples from

Bagot's Park dated to the 14th century and three samples from sites 15b. 17 and 3 dated to the 15th/16th century

- Meek, 2011: 25 samples from Bagot's Park (17) and Little Birches (8) dated to the early and mid-16th century
- Freestone et al., 2010: consumption data from 12 samples of 15th century window glass from York Minster. Purchase records suggest that the glass was sourced from Staffordshire

2.16 Using the regional data to provenance

Table 2.6 below is a tabulated summary of the regional compositions, as mentioned above. It lists the main compositional points for each regional production area and shows the code (for example, FR A1, FR C1, FR F1) that has been assigned here to each different regional composition. The codes and different colours assigned to each region/country are used throughout the thesis when reporting the provenance of the study glasses.

2.17 Summary of glass and glass production

This chapter has presented a summary of the chemistry of glass and of glass production in northern Europe and provided a foundation with which to examine glass consumption at monastic high status sites in England. It has shown that glass composition was not only influenced by the diversity of the raw materials and different workshop practices, but also the organisation of the craft, particularly in England through the family pattern of 'kinship groups'. The following chapter provides the historical, social and economic context for the study, from the Norman Conquest in the 11th century to the Dissolution of the Monasteries in the mid-16th century.

Table 2.6 Tabulated summary of the regional compositions listing the main compositional points

Source	**Country**	**Region**	**Sub-band**	**No. samples**	**High %** Shown as element	**Low %** Shown as element	**Ca:K**
Gratuze, unpublished	France	C13 NW	**FR A1**	9	Na, Mg, K, P	Si, Al	1
Gratuze, unpublished		C13 NC	**FR A2**	5	Na, Mg, Fe	Si	1.1
Gratuze, unpublished		C14 NW	**FR A3**	10	Na, Mg,	Fe	0.9
Gratuze, unpublished		C13 NC	**FR B**	47	K	Na	0.9
Gratuze, unpublished		C13 NC	**FR C1**	3	Mg, Fe	Mn	1.1
Barrera & Velde, 1989		C14 NW	**FR C2**	3	Na	Mn	1.1
Barrera & Velde, 1989		C14 NC	**FR C3**	22	Mg, K	Ca	0.9
Gratuze, 2101; Barrera & Velde, 1989		C14 NW	**FR D**	14	Na, Mg, K	Ca, Al	0.7
Gratuze, unpublished		C15 NW	**FR E1**	12	Mg, Si	Al, P, K, Mn	1.2
Barrera & Velde, 1989		C15 NC	**FR E2**	3	Na, Mg, Si	Al, P, K, Mn	1.1
Barrera & Velde, 1989		C14 E	**FR F1**	34	Ca, Fe	Na, Mg, K, Mn	1.5
Barrera & Velde, 1989		C14 E	**FR F2**	11	Ca, Mn	Na, K, Fe	1.4
Mortimer, 1997; Paynter in preparation	England	C13/14 ST	**ENG ST**	11	Na, Mg	K	1.6
Paynter, in preparation		C14 ST	**ENG ST**	9	Na, Mg, Mn	K	1.4
Freestone et al		C15 ST	**ENG ST**	12	Na, Mg, Mn	K	1.5
Paynter, in preparation		C15/16 ST	**ENG ST**	3	Na, Mg, Mn	K	1.1
Meek, 2011		C16 ST	**ENG ST**	25	Na, Mg, Mn	K, Ca	1.1
Meek, Paynter/Dungworth, Merchant, Welham		C14 TW	**ENG TW**	43	Na, Mg	Al, K, Ca	1.2
Wedepohl 1997	Germany	C13	**GER A**	13	K, Ca, Mn	Na, Si, P	1.2
Wedepohl 1997		C15	**GER B1**	3	Al, P, Ca, Fe	Na, Si, K	1.7
Wedepohl, 1996		C14	**GER B2**	16	Al, P, Ca	Na, Si, K	2.4
Wedepohl 1997		C15	**GER C**	13	Na, P, Ca	K	4.5
Wedepohl 1997, Cilova et al., 2015	Central Europe	C14	**BOH A**	10	K, Ca	Na, Si, P	0.8
Cilova & Woitsch 2012		C15	**BOH B**	8	K	Na, Al, P, Mn	0.8

Chapter 3

3. The historical context of the 12th to 16th centuries and its relevance to the consumption of window glass

3.1 Introduction

The asset-stripping of the wealthy English Monasteries during the Dissolution of the Monasteries in the mid-16th century produced a substantial redistribution of commodities and wealth. The disposal of goods for the benefit of the Crown finances was judiciously controlled and the process of dismantling the buildings and redistributing the wealth was conducted quickly. While the portable wealth was retained by the Crown, other materials such as copper alloy, lead and even decorated stonework were salvaged and sold (Willmott, 2020, p. 29, 33). Documentary evidence shows that window glass was divided into three grades: the first-grade glass was retained for use by the Crown; the second-grade was sold, generally at auction; while the third-grade glass was stripped of its lead came and dumped (Fergusson, Harrison and Coppack, 1999, pp. 180, 229). The third grade glass included unfashionable designs such as 13th century grisaille, windows with overly religious themes that were not desirable for a secular re-use - and windows from a range of dates that were weathered or damaged, perhaps including those also damaged during removal. It is this discarded 'third grade' glass that has been retrieved from dissolution deposits at seven monastic sites that forms the research material used in this study.

This chapter discusses, with particular reference to monastic window glass, the circumstances that led to the prosperity of the monasteries and the devastating effects of the Black Death and the Hundred Years War. The economic and social backdrop to the medieval period is considered along with trade links with Europe and the transportation network in England and continental Europe that was used to transport the window glass. The manner in which wealth was displayed through the elaborate windows and the architectural evolution that supported this display of devotion to god are described, and the role of the printing press in triggering religious change that led ultimately to the Dissolution of the Monasteries in England is examined.

3.2 The context of English social and economic life

Between the 10th and the mid-13th century, England was a prosperous and politically stable country. Warmer temperatures combined with improvements in the technology of farming helped increase agricultural production and drive a population explosion. At the time of the

Domesday survey the population of England was between 1.2-1.6 million and had risen to around 4.8 million by around 1348 - just before the Black Death (Hatcher, 1977, p. 71; Senn, 2003, p. 522; Broadberry *et al.*, 2010, p. 23; Easterbrook, 2011, p. 1). The majority of people during this period were peasants, working for a lord in return for land, and living in nucleated villages (Homans, 1953, p. 40; Bean, 1968, p. 1; Vasillu, 2019, p. 1). In many ways the situation was similar in France with a peasant population tied to the land (Le Roy Ladurie, 1987, p. 8). In Germany the colonisation of the forests had led to free peasant communities, and at least until the 13th century there was freedom of movement for serfs. This was through 'Stadtluft macht frei' (city air brings freedom) whereby a serf could attain their freedom by residing in a city for a year and a day (nach Jahr und Tag) (Higgs, 2017, p. 318). As England became more affluent, merchants, artisans, labourers and emigres from the continent were attracted by the growing work opportunities in England's cities, towns, and countryside, and rural-based industries that exploited the local natural resources included iron making, tanning, pottery and glassmaking (Thrupp, 1957, p. 267).

By around AD 1300, approximately 10% of the English population lived in towns that were supplied with produce and materials from their hinterlands, the largest of which surrounded London (Senn, 2003, p. 524). People were employed in crafts such as pottery, leatherwork, metalworking and glass painting, but also as merchants using the regular local fairs to trade. However, unsustainable economic expansion in England and a change in the climate put a toll on the land (Ziegler, 2008, p. 32). Harsh winters, disastrous harvests, high food prices, a shortage of firewood and the Great Famine of 1315-17 diminished the population, but it was the Black Death in the mid-14th century that devastated it. By 1377 the population of England was less than 2.5 million (Hatcher, 1977, p. 71).

3.3 Trade with Europe and the movement of glass and glassmakers

English trade with continental Europe in the medieval period was facilitated through the many maritime ports situated around the English coastline. Several had been in operation since before the Norman Conquest including the Cinque Ports Confederation in the south-east (Hastings, New Romney, Hythe, Dover and Sandwich), and the Port of London, which was established by the Romans in 1st century AD (Sayles, 1961, p. 186). Bristol was a major port on the west coast with easy access to France from where cloth, wine and salt were imported (Miller, 1964, p. 27; Lipson, 1956, p. 186) and on the east coast, trade with the Low countries and Germany generally went through Hull, Grimsby and, for example, a new port at Boston. This included the export of grain and high-quality wool produced by the monasteries. The Hanseatic League dominated the haulage of goods between the continent and eastern and northern England. This was a confederation of towns and merchant guilds in central and northern Europe that developed in the 13th century into a mutually beneficial trading (and defensive) network (Gareau, 1982, p. 102). Competition for north European trade came from the Company of Merchant Adventurers, founded in London in the 15th century largely for the

export of wool and the import of goods including wine, metals and salt (Lipson, 1956, pp. 186–7).

From at least the Norman Conquest until the 13th century, all glass was imported into England from the continent. The same ports that were used for the movement of wool and wine were also used to facilitate the trade in window glass. Both the Hanseatic League and the Company of Merchant Adventurers maintained warehouses in London and York to store and manage the distribution of this glass (Lingelbach, 1902, p. 19). Surname evidence demonstrates that from the 13th century many of the glassmakers working in the nascent English glassmaking industry were immigrants from France, Germany and the Low Countries. The earliest surname reference from the Weald is a deed relating to Laurence Vitrearius whom Winbolt (1933, p. 7) suggests came from Normandy and who in 1226 leased land. In Staffordshire names include Thomas and Simon le Glasemon (Welch, 1997, p. 2). A further group of emigre glassmakers from Normandy and Lorraine settled in the Weald in the 1560s (Winbolt, 1933, p. 13). See section 2.10.1).

3.4 Monastic expansion

The 11th century was a period of monastic expansion. Battle Abbey was founded in 1067, and others that followed include the abbeys in Canterbury, Gloucester, Norwich and Tewkesbury (Midmer, 1979, p. 4). Many monasteries were founded as alien priories, controlled and financially beholden to their French mother houses and who may therefore have influenced the sources of building materials and choice of glass supply (there are no alien priories in the study, however). Other monasteries, including Rievaulx were colonised by French monks (Fergusson, Harrison and Coppack, 1999, p. 45; Platt, 1984, p. 4; Fletcher, 1954, p. 214) (see section 5.2). The ecclesiastical establishments were powerful and rich (Senn, 2003, p. 528); Peyton (2020, p. 3) reports an estimate that in 1340 the church owned about 30% of the land. Religion played a central role in the lives of the English people and life revolved around the religious calendar, but the priority for religious establishments during the medieval period was to alleviate the perceived threat from the devil (Burns-Price, 2021, p. 57). As the majority of the population was illiterate, imagery of the devil, and demons, and representations of the perils of a debauched lifestyle were commonplace (see 3.7 below). Decorated windows were a very accessible art form and were thus powerful tools to influence morals through doctrine, while in a monastery, decorated windows also served to encourage contemplation and reflection. Although most lay brothers would have been illiterate, most choir monks would have been able to read and therefore passages from the bible and names of donors painted onto the windows were also commonplace.

3.5 The Hundred Years War and the glassmaking hiatus

The Hundred Years War (so named in the 19th century), was a period of intermittent conflict between England and France over 116 years between 1337 and 1453. Anglo-French relations were, however, already hostile before 1337 and certainly continued to be so after 1453 (Green, 2014, p. 3, 249). Ultimately, the French retained control over the Kingdom of France but the conflict caused great divisions between the two countries, as demonstrated in a rise in English nationalism. In 1362 English replaced French as the official language of England, and alien priories, Arundel Priory for example, were financially penalised by the Crown (Elvins, 1981, p. 4). The war had bankrupted England as resources had been diverted, and consequently trade had declined, and merchant ships from all nations crossing the channel were in danger of attack (Green, 2014, p. 151). In Normandy, Brittany and the north-central region around Paris in particular, the war had devastating effects: looting by English soldiers and the destruction of enemy territory, 'chevauchee' (Green, 2014, p. 12), exacerbated the impact of the plague and created a situation of famine and an abandonment of the villages ('wüstungen') (Le Roy Ladurie, 1987, p. 25-30, 37). Glassmaking activity, known in these areas at least from the early 14th century, was undoubtedly affected along with all other aspects of rural life. When settlement was resumed, at least by the 15th century, glassmaking may have taken advantage of new areas that had been created by the natural conversion of abandoned farmland to woodland (Le Roy Ladurie, 1987, p. 43). Nonetheless, as Adlington et al. describe (2019, p. 10), the hiatus in glassmaking may have led to a loss of some glassmaking skills, for example for the production of coloured glass

3.6 The Black Death

Mid-14th century Europe was devastated by an epidemic of bubonic plague, now known as the Black Death, that killed around one third to half of the population (Senn, 2003, p. 510; Ziegler, 2008, p. 236, 240; Byng, 2017, p. 13). The impact of the plague on society, economics and on culture was catastrophic; as Horrox notes, it was seen by contemporaries to herald the end of the world (1994, p. 3). Originating in Central Asia in 1339, the disease spread with speed along trade routes. It reached southern Europe in 1347 and England just a year later and within two years had destroyed the populations of many towns and rural communities. In France the plague was called le Morte Bleue, the Blue Death, and between the 14th century and 15th century repeated epidemics of le Morte Bleue reduced the overall population by 40%. In the heavily populated rural areas of Normandy, which was simultaneously suffering from the consequences of the Hundred Years war the population was reduced by 75%. A similar pattern of rural decline due to the impact of the Black Death was seen in Germany (Le Roy Ladurie citing Sivery, p.31).

For several years Europe was incapacitated. Overseas trade was disrupted through fear of contagion from infected sailors, agricultural fieldwork was neglected because of the high mortality of the peasant communities and the effects of the Black Death 'paralysed for a time every art and industry' (Gasquet, 1893, p. 203). In England, such was the demand for agricultural workers that the feudal system of work and tenancy was supplanted with a waged system, essentially because the effect of the Black Death was to 'put a premium upon the services of those who survived' (Gasquet, 1893, p. 196). Field rents were reduced and on many monastic estates land was broken up and sold (Senn, 2003, p. 517; Madsen, Robertson and Ye, 2024).

3.6.1 The effect of the Black Death on the monasteries

In England by 1350 around half of monastic communities had perished, including lay brothers and more than one hundred abbots (Ziegler, 2008, p.273). The Louth Park Chronicle, dated to around 1413 mentions the death of 'many monks' at the abbey, among them the abbot Dom Walter de Louth (Horrox, 1994, p. 67; Locking, 2022, p. 43). The loss of the lay brothers, the demise of the grange system, and the reduced revenue from tithes and pilgrimage pushed many monasteries into debt and so demesne land was leased or sold to tenants to raise capital (Carter, 2019, p. xlv). Marks (1993, p. 166) states that by the mid-14th century many large monastic building and refurbishment schemes were completed, and fewer large glazing schemes were commissioned. At some monasteries the range of claustral buildings in use required remodelling or constricting to accommodate the smaller communities: at Alcester for example, the abbey was absorbed by Eynsham Abbey and downgraded to a priory (Styles, 1941, p. 20) (see section 5.5.1). Throughout the 14th century and into the 15th century further sporadic outbreaks of the Black Death occurred in England and the recovery of the religious houses was intermittent (Fergusson, Harrison and Coppack, 1999, p. 57; Locking, 2022, p. 51).

3.6.2 The role of religion in the aftermath of the Black Death

In the mid-14th century, the reputation of the church suffered as a result of the catastrophic loss of life, and the authority of the church and religious houses was questioned. Nonetheless, in the decades that followed the Black Death, particularly in the 15th century, a religious revival swept through Europe (Koyama, Johnson and Jedwab, 2020, p.38). This was due to a fear of the plague returning as much as a fear of the new social structure that resulted from the empowerment of the peasantry. The church was thus regarded as 'the dyke which held back the flood of anarchic insurrection' (Ziegler, 2008, p. 277). The renewed religious dedication was manifested in the construction of new parish churches and the founding of chantry chapels by private donors who included the nobles and elite as well as wealthy farmers (Ziegler, 2008, p. 276; Byng, 2017, p. 14). Private donors also funded new stained-glass windows in monasteries in exchange for prayers by the monks for a good life, and also for a 'good death' and the salvation of their souls, often incorporating their own image into the window design (Marks, 1993, p. 10; Dugdale, 2010, p. 23; Márkus, 2025, p. 554). In the longer

term however, the challenge to the papacy and the authority of the Catholic church in Europe preceded the Dissolution of the Monasteries in the 16th century (see sect 3.9 below).

3.6.3 Dearth of skilled glass workers

In the aftermath of the Black Death in England, surviving skilled craft workers such as glassmakers and glaziers were sought after. Pre-pandemic, glass painters were numerous and established in the bigger towns and cities where the main cathedrals and great churches were being built, such as Lincoln, Norwich, Chester and Coventry (Knowles, 1922, p. 344). In 1351 glaziers predominantly from the midlands and western counties were forced to work on the glazing of the chapels of St George at Windsor, and St Stephen in the Palace of Westminster, both commissioned by Edward III to celebrate victory at the Battle of Crecy. Colourless English glass was supplied from Chiddingfold in the Weald and records show that Hanseatic League merchants were 'impressed' to supply coloured continental glass that was being stored in their London warehouses (Knowles, 1922, p. 343). There was still a shortage of glaziers and masons in the late 14th century, a situation that delayed the glazing of ecclesiastical buildings such as York Minster and Gloucester Cathedral, although by the early 16th century numbers appear to have recovered and most towns had a glass painter (Aubrey cited in Knowles, 1922, p. 343). In contrast, glasshouses in England were probably always few in number; Kenyon suggests that only one or two glasshouses were operating in the Weald at any one time until expansion in the mid to late 16th century (see section 2.10.1).

3.7 Printing

The invention of printing had a profound effect on the monasteries, not least by diminishing their role in the production of religious texts through the hand-copied manuscripts, but also in the spread of religious ideals in the Protestant Reformation and the mass circulation of new forms of visual imagery that were used in decorative window schemes. The first printing press using movable metal type was invented around 1450 in Mainz in Germany, and by the end of the century more than half of the major European cities had a press and around 8 million books had been produced (Eisenstein, 1979, p. 45; Dittmar, 2011, p. 1133). Publications included maps, calendars and dictionaries in addition to scientific books about glassmaking, describing recipes and techniques, for example by Biringuccio in 1540 and Agricola in 1556. Biringuccio's book, *De la Pirotechnia*, written in Italy in 1540 devotes a chapter to European techniques of glassmaking (Smith and Gnudi, 1990, pp. 126–133), and Agricola, who was a German mineralogist produced *De Re Metallica* in 1556 in which recipes and methods of producing forest glass are described (Hoover and Hoover, 1950).

The production (and dissemination) of printed material at this time had, as asserted by Eisenstein (1979, p. 38), a social, economic and intellectual impact on European civilization. The message of the Reformation, for example Luther's treaties, was spread

predominantly by printing (described by Luther as 'an unquenchable flame') and paved the way for the Protestant Reformation in northern Europe in the early 15th century (Holborn, 1942, p. 137). The production of printed material was not new; woodblocks were already used at least by the early 15th century printing fabrics, block books that included *Ars Moriendi* (Art of Dying) and devotional woodcuts carrying religious imagery (Brown, 2019, p. 13). *Ars Moriendi* was in essence a self-help guide to 'a good death' in an age of recurrent bouts of the bubonic plague and a shortage of priests to attend to the dying (Márkus, 2025, p. 554; Dugdale, 2010, p. 23). The book contained woodcut illustrations portraying angels, saints and the devil, and imagery of the temptations that were to be avoided to secure a good death (Imhof, 1997, p. 194) (figure 3.1). These themes were popular and were represented in many

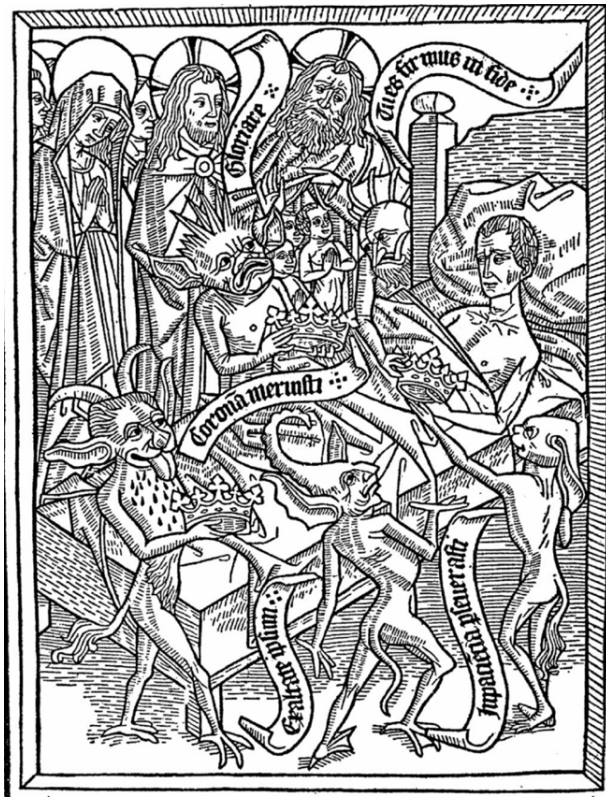


Figure 3.1 Demons and devils depicted on a Dutch woodblock book printed by Johann Weissenburger at Nuremberg, c. 1510 (British Museum, no. 1904,0206.127)

Figure 3.2 The same type and style of imagery is seen on the 14th century window at Stanford on Avon (nii, CVMA 1603), c. 14th century first half (www.CVMA.ac.uk)

of the visual arts, including decorated window glass (e.g. figure 3.2); likewise, the thick outlines and hatching of wood cut prints emanating from Germany and the Low Countries were also copied by the glass painters working in York and the North Sea coast (Hogan, 1940, p. 580; Baker, 1978, p. ii). *The Biblia Pauperum* (c. 1464) was another block book that acted as a picture-bible and influenced the imagery used in windows, such as the Holy Trinity at Tattershall, dated to the last quarter of the 15th century (CVMA 20995) and in the west wall of St. Mary's, Fairford, dated to around 1500 (Brown, 2019, p. 12). Factors influencing glass decoration and the influence of the wood-cuts are discussed further in sections 4.3. Although after the study period, another example of a block book is *Foxe's Acts and Monuments* (1563),

which was a propagandistic Protestant history of the church, and which was used to cement the new official religion in England (figure 3.3).

Figure 3.3 Foxe's Acts and Monuments (1563), which was a propagandistic Protestant history of the church, here showing windows being uninstalled. It is known that some windows, for example at Rievaulx Abbey, were carefully removed for re-use (translated) particularly in parish churches (Willmott, 2020, p. 44)

3.8 Monastic Orders and the Dissolution of the Monasteries

The following section provides an overview of the Benedictine and Cistercian religious orders, their architecture with reference to the glazing, and the dismantling of the monastic buildings during the Dissolution in the 1530s. This provides the contextual information for discussing glass consumption according to religious order, the use of glass in the different buildings and locations in the abbeys, the influence of Gothic architecture on the development of decorated windows, and the deliberate deposition of the window glass that forms the basis of the research material.

3.8.1 Benedictine and Cistercian Orders

3.8.1.1 Benedictine Order

The Order of Saint Benedict, which originated in Italy in the 6th century from the teachings of St Benedict is the oldest religious order in the western church. The order established monasteries in England during the 7th century including the double monastery at Monkwearmouth-Jarrow. The period following the Norman Conquest in the 11th century was an era of expansion; monasteries were established (importing monks from France), and along with castles, they were used by the Normans as an instrument of conquest and settlement (Shelby, 1976, p. 91). As with most other orders, the Benedictines reached their zenith in the

early 13th century before declining in the 14th century, primarily due to the devastation of the Black Death (Butler and Given-Wilson, 1979, p. 72).

Benedictines monasteries in the medieval period were self-governing and autonomous, and unlike Cistercians were not obedient to a mother house. They were, however, connected by their shared obedience to the rule of Saint Benedict (Lawrence, 2001, p. 18, 26, 29). Benedictine houses were richly endowed with land and property, and they received income from rents, tithes and pilgrimage, and their land was farmed using the help of hired labour and servants. Increasing wealth in the 13th century led not only to the construction of magnificent monastic buildings but also allowed the choir monks to focus on scholarly and artistic pursuits (Fletcher, 1954, p. 262, 266). The Rule of St Benedict emphasised community living, and prayer and work: 'Ora et Labora'. All branches of art were taught and practiced; some Benedictine monks were artisans - the metalworker Roger of Helmarshausen (who is generally accepted to have been Theophilus), for example (Fletcher, 1954, p. 262; Hawthorne and Smith, 1979, p. xv). Important Benedictine buildings were richly ornamented, and the choice of decoration was considered and symbolic. Windows were richly coloured and decorated, for example Canterbury Cathedral, formerly the Benedictine monastery Christ Church (see Michael, 2014), although the more restrained and simpler grisaille glazing schemes initiated by the Cistercian order were also employed, for example at Battle Abbey (Kerr in Hare, 1985).

3.8.1.2 Cistercian Order

The Order of Cistercians was founded in 1098 by Benedictine monks wanting a stricter way of life, that of simplicity, silence and poverty in a religious community (Midmer, 1979, p. 7). They rejected donations of cultivated land and property in favour of wilderness and marginal land, which they farmed using a workforce of lay brethren and laymen. The main period of foundation in England is 1128-1153. The first Cistercian monastery founded in England was Waverley in Surrey in 1128, followed by Rievaulx in 1131. New monastic foundations were spawned from existing monasteries in a network similar to that of a family tree, all with a lineage to Citeaux in Burgundy, north-central France. This system of foundation gave rise to the rapid expansion of the Order (Butler and Given-Wilson, 1979, p. 34; Midmer, 1979, p. 7). As with the Benedictines and other Orders, expansion plateaued in the 13th century before declining (Butler and Given-Wilson, 1979, p. 72).

The Order was regulated and controlled centrally from the mother house in Citeaux and enforced through a system of mutual supervision, with each individual house also owing obedience to the house from which it was colonised (Lawrence, 2001, pp. 175-76). As a result, there was unity, order and standardisation; in architecture for example, where the early stonework was devoid of elaborate decoration, and in the monotone grisaille glazing schemes (Lillich, 1973, p. 69; Butler and Given-Wilson, 1979, p. 34; Brooke, 1986, pp. 17, 23) (see section 4.4.1). However, in the late 12th century-early 13th century, with their increasing

wealth derived predominantly from farming and the export of high-quality wool, there was a gradual abandonment of the original principles of simplicity and plainness in Cistercian art and architecture (Norton and Park, 1988, p. 7). Thus, the buildings became more beautiful. Sumptuous Chapter Houses were constructed, and refectories were built 'on a positively monumental scale' (Norton and Park, 1988, p. 193; Butler and Given-Wilson, 1979, p. 37, 38; Deuchler, 1989, p. 10). By the early 13th century, Rievaulx, for instance was larger and grander than most Benedictine monasteries in Britain (Norton and Park, 1988, p. 7). In window decoration, colour was introduced in the 13th century and while monotone grisaille continued to be used into the 14th century, it was side-lined to borders while more decorative and colourful decoration took centre stage (see section 4.4.1).

3.8.2 The monastery builders

Documentary evidence shows that monks were sometimes involved in the conception and design of monastic buildings, for example Alan de Walsingham from Ely Monastery who designed the Octagon at the centre of the monastic church (now Ely cathedral) (Dugdale et al., 1817, p. 468). The relationship between architect, who was a freeman and master mason, and monks is illustrated in a contract from Durham Cathedral Priory in 1398 between the Prior and monks (the patron), and the master mason, John de Middleton to build new dormitory. The contract stipulates the construction of tracery is to be similar to those that had already been installed in the cathedral, plus other buildings that were cited as models (Shelby, 1976, p. 91, 94). This example highlights the duplication of architectural features such as windows or carvings from other, usually local and newly built, ecclesiastical 'source buildings', that was a standard practice in the medieval period.

3.8.3 Great windows of Gothic architecture

Prior to the 12th century, monasteries in England were built in the Romanesque or 'Norman' style, which was characterised by rounded arches, thick walls, small windows and dark interiors. From the 12th century the new and the remodelled monasteries used an innovative new architectural style, the Gothic, which was used by both Benedictine and Cistercian orders. This style spread throughout northern Europe concomitant with the spread of Roman Catholicism (Camille, 1996, p. 12; Grodecki, Prache and Recht, 1986, p. 15). The first Gothic building in Europe is St Denis Cathedral in Paris, consecrated by Abbot Suger in 1144. In England, early Gothic structures included the rebuilt east-end of Canterbury Cathedral following the fire in 1174, Wells Cathedral 1175-1260, and Lincoln Cathedral, around 1191.

Gothic architecture is a consistent and repetitive system of absolute or relative dimensions and proportions and is epitomised by the pointed arch, ribbed vaulting and flying buttress. It is far more versatile than the round-arched Roman style, which necessarily relies upon the strength of the walls. The pointed arch allows the weight of the vaulted ceiling to be directed downwards through piers or columns, with the lateral thrust of the building constrained or

held in place by standard and flying buttresses. Therefore, the walls do not support the structure, instead they enclose it (Fletcher, 1954, p. 329). These features enabled medieval ecclesiastical structures to be built taller with slender columns and thinner, lighter walls (Grodecki, Prache and Recht, 1986, p. 7).

The absence of thick, supporting walls in the medieval monastery created a cavernous interior space that enabled vast areas of glazing to be installed. This provided light in the practical sense, for reading or for performing everyday tasks (Fletcher, 1954, p. 370), and an ethereal, coloured light that enhanced the spiritual atmosphere of most notably the nave of the church. Grodecki (1986, p.14) claims that 'the Gothic space is not merely an enclosed volume to be geometrically defined; it is a function of light; it is transfigured by light'. Accordingly, light - the symbol of the grace of God, colour from the decorated panes and space combined in monastic churches to create a sense of the heavenly on earth.

3.8.4 Chronology of window design 11th - 16th century

As Gothic architecture evolved so the shape and size of the window openings evolved. This is shown in table 3.1, which summarises the chronology of Gothic architecture with reference to the fenestration. The Early English style of the 12th century and 13th century is characterised by tall, narrow lancet windows with traceried heads; in the 14th century, the windows become larger with ornate tracery. By the 15th century, the windows of the Perpendicular style were wider and strengthened using horizontal transoms, and taller to emphasise the height of the buildings by way of vertical mullions and tracery (Fletcher, 1954, pp. 348–352).

Table 3.1 Evolution of the shape and size of the Gothic window openings, with English examples

Period	Window architecture	Examples
Norman 1066 to late C12	Small round-headed single lancet windows piercing supporting walls (figure 3.4)	Durham Cathedral
Early English Late C12 to early C14	Vertical mullions and small traceried heads, lancet windows grouped together under a single arch (figure 3.5)	Salisbury Cathedral
Decorated late C13 to late C14	Large windows with ornate, geometrical and flowing tracery and stone mullions with an expanse of glazing (figure 3.6)	York Minster nave and Chapter House
Perpendicular Late C14 to early C16	Huge windows strengthened by horizontal transoms and vertical mullions with an emphasis on height, verticality and vast expanses of glazing (figure 3.7)	Beauchamp Chapel and many Oxford colleges
Tudor Late C15 to mid C16	Similar to Perpendicular but now seen in domestic buildings	Parts of Hampton Court

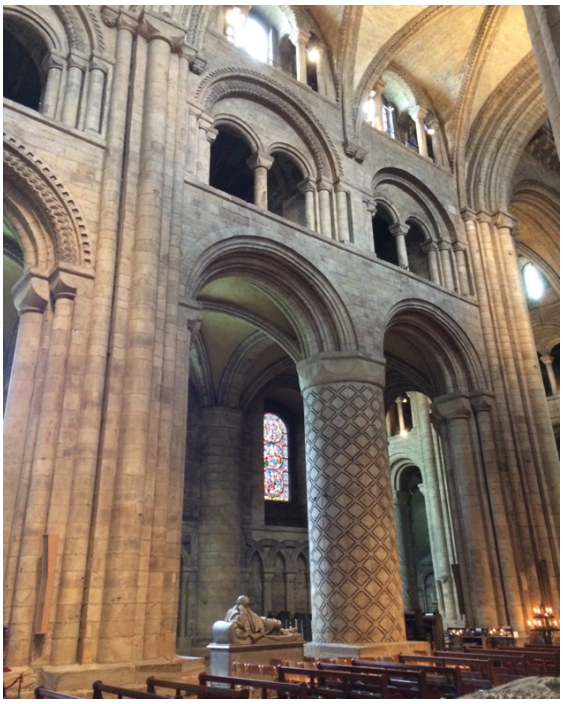


Figure 3.4 Romanesque architecture, Durham Cathedral (C11/12). Photo by David Simpson, https://englandsnortheast.co.uk/durham-cathedral/, 1991-2024

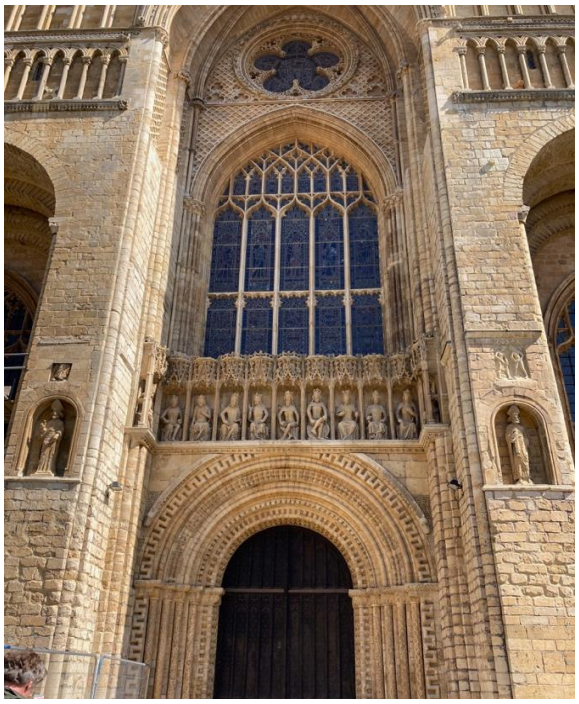


Figure 3.5 Early English architecture, Lincoln Cathedral (1270s). Photo by B Stone, author

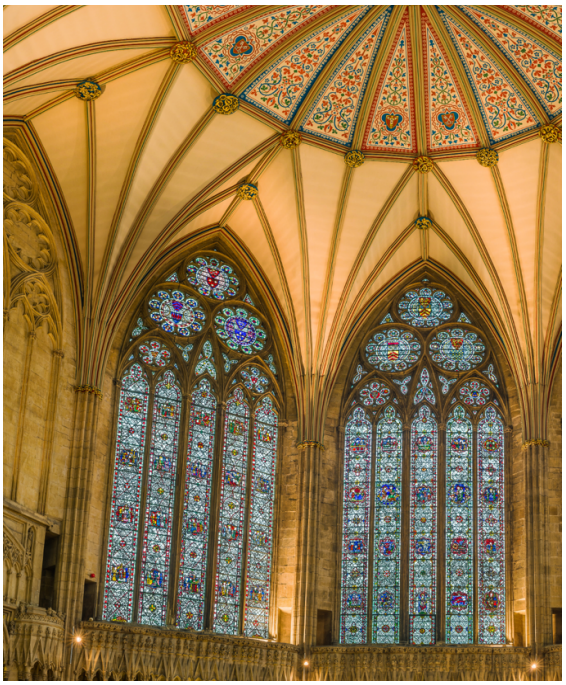


Figure 3.6 Decorated architecture, York Minster Chapter House (1275-90). Photo by David Iliff. License: https://creativecommons.org/licenses/by-sa/3.0/

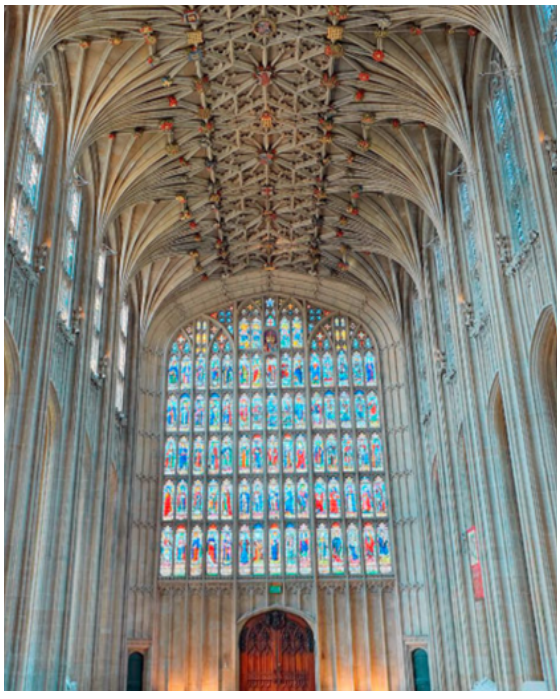


Figure 3.7 Perpendicular architecture, St George's Chapel, Windsor Castle (1506.) https://www.nationalchurchestrust.org/church/st-georges-chapel-windsor

3.8.5 Monastic architecture

During their lifetime most monasteries underwent frequent reconstruction, alteration, and upgrading into the contemporary style (Fletcher, 1954, p. 366). As fortunes fluctuated the monastery might finance new and grander buildings, including new glazing or conversely, to adjust to declining numbers, by shrinking or repurposing buildings. This latter point is demonstrated at Rievaulx Abbey when, in the mid to late 14th century, key buildings in the claustral range were remodelled to accommodate a much-reduced community (Fergusson, Harrison and Coppack, 1999, p. 101).

The Cistercian Order was reclusive and sought isolation and self-sufficiency, taming the wilderness into productive farmland (Fletcher, 1954, p. 266). Accordingly, donors were happy to bestow wasteland on new Cistercian monasteries, Bordesley Abbey for example, settled on boggy ground and fought a continuous battle against subsidence that included the installation of a sump, or stone basin to collect the excess water in the transept area of the church (Rahtz and Hirst, 1976, p. 90). Benedictine monasteries were sometimes established on landed estates - Denny Abbey in Cambridgeshire for example, or on sites of older ecclesiastical estates in order to establish themselves quickly and gain stability, for example Whitby Abbey (see section 5.2). The Benedictine monks of Bardney Abbey rejected the first waterlogged site that was offered by Gilbert de Gant (or Ghent), Earl of Lincoln in favour of a more stable environment, and Laing describes how the abbey was endowed 'liberally' at its foundation (Laing, 1914, p. 2).

3.8.5.1 The Benedictine Plan

New monasteries sought a level site that was supplied with water and other resources such as wood for building and fuel. The Gothic monastery was a complex of buildings with inner and outer courts enclosed by precinct walls that deliberately isolated it from the outside world. The standard layout was compact with an inner court that contained the important buildings such as the church and Chapter House, and an outer court containing ancillary buildings (figure 3.8). The church was therefore the heart, with the complex of buildings resembling a village (Fletcher, 1954, p. 26). Most monasteries followed the Benedictine Plan in terms of the layout of the main buildings in the complex, although there were some differences between Benedictine and Cistercian monasteries, as shown in table 3.2 below.

Almost all medieval monastic churches were aligned east-west (Rievaulx is one exception that is aligned northwest to southeast because of the site restrictions, see chapter five, section 5.5.6). The plan was in the form of a Latin cross with the short arms as north and south transepts containing side chapels and chantries. The church was the biggest and most important building, sited on the north side to allow light to rest of the complex. In some larger churches, extra apsidal chapels were built in response to increasing numbers of recruits (Norton and Park, 1988, p. 6). The eastern arm contained the high altar, the choir and sanctuary, while the longer western arm contained the nave and the west entrance. Along the

north and south sides of the nave were aisles. There was normally a tower (sometimes tapering into a spire) usually above the crossing of the north and south transepts that would house the bells. Doors led from the north transept to the cemetery, and from the south transept to the night stairs and monk's dormitory and onto the cloister (Fletcher, 1954, p. 333); (Cook, 1960, p. 19).

The cloister court was usually sited on the south side of the church to maximise daylight and shelter from the north wind. It comprised the garth, a square or rectangular open area of ground, surrounded by a covered walkway. It acted as a conduit connecting other buildings in the inner court of the monastic range with the church but was also a place of quiet contemplation and study. From the early 13th century some cloisters were glazed. Examples can be found in monasteries from all monastic orders although they were mostly found in Benedictine cloisters such as Peterborough, Westminster and Gloucester, which were all glazed by the 15th century with figural windows (Hayward, 1973, p. 93). The Chapter House was in the eastern range and was second in importance to the church. It was where the professed monks gathered and the ecclesiastical business of the monastery was undertaken (Guilford, 1912, p. 114). In the upper storey of the eastern side of the cloister was the dorter, which is the dormitory, with a night staircase leading to the church. To its east was the reredorter, the communal latrine, below which was a drain and the warming-house. Other buildings off the cloister were the frater or dining room, the kitchen, the cellarage and the lavatorium or communal wash-room. It was usual for the abbot's lodgings to be found on the western side of the cloister and the lay brothers' and guest accommodation. Other buildings in the inner court were the sacristy, where the priests prepared for mass, the infirmary, and the library and scriptorium, the writing room, south facing to utilise the best light (Cook, 1960, pp. 20–21).

Outside of the main group of buildings were ancillary buildings, the range dependent on the size of the monastery. They included granaries, stables, fishponds, a bakehouse, brewery and other buildings connected with crafts and industrial activities. At Rievaulx and Bordesley abbeys, archaeological evidence shows structures relating to metal working (Fergusson, Harrison and Coppack, 1999, p. 183; Rahtz and Hirst, 1976, p. 119). The gatehouse, which was sometimes fortified, contained guests' rooms and, as at Bordesley Abbey, a lay chapel (Astill, Hirst and Wright, 2004, p. 106).

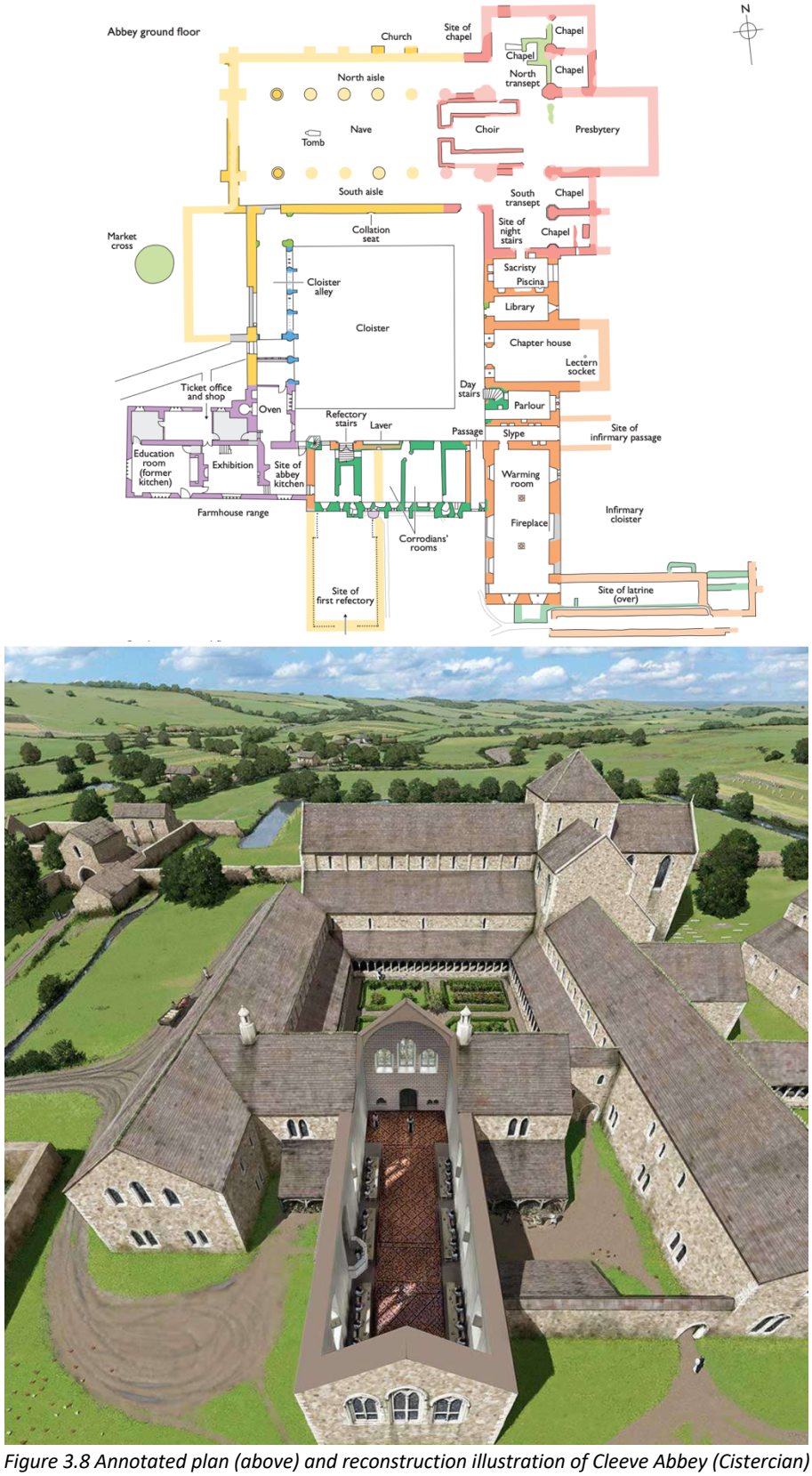


Figure 3.8 Annotated plan (above) and reconstruction illustration of Cleeve Abbey (Cistercian) in Somerset (below). (www.english-heritage.org.uk/visit/places/cleeve-abbey/history), illustration by Peter Urmston

The Cistercian order built their monasteries in remote locations, and construction was sometimes challenging, for example if the ground was boggy or hilly then the layout and orientation of the monastic range was adapted to that landscape. As such, no two Cistercian monasteries are alike (Coppack, 2000, p. 105). Rievaulx for example, is built on a north-south axis, adapting to the topography of the site (see 5.5.6). However, numbered stones at Rievaulx Abbey suggests that the church may still have been of a modular construction, designed off-site to a typical plan and stones numbered at the quarry (Fergusson, Coppack and Harrison, 1999, p. 76).

The architectural differences between typical Benedictine and Cistercian monasteries include aspects of the layout of the complete complex. For example, in Cistercians houses the kitchen was more connected with the western range to accommodate the lay brethren, and there were differences in the shape of buildings such as the Chapter House, which in Benedictine houses was usually octagonal. Some of the architectural differences are listed in table 3.2 below.

Table 3.2 Some examples of architectural differences between Benedictine and Cistercian monasteries

Architectural feature	**Benedictine**	**Cistercian**	**Reference**
Stone-built bell tower	Present	Absent until 15th century	(Fletcher, p. 262, 379)
Eastern arm	Full length	Sometimes shortened	(Fletcher, p. 262, 379)
Modular construction	Non-modular construction	Modular construction suggested by numbered stones, e.g. at Rievaulx	(Coppack and Harrison, 1999, p. 76)
Chancel	Round-ended	Square-ended	(Cook, 1960, pp. 19–21, 47)
Nave	Laity could use	Laity could not use	
Aisles	Present	Absent	
Chapter House	Octagonal	Rectangular, rounded apse end	
Western facade	Highly decorated	Plain	
Kitchen	Outside cloister	Within cloister	
Frater	Inside cloister	Orientated to allow room for the kitchen in the cloister, to serve the monks and lay brethren in the western range	
Warming House	Integral	Sometimes a separate building east of frater	
Elevation	Up to 3 storeys	Up to 2 storeys	

3.8.6 Monastic glazing

The type of glazing and decoration that was used in a monastery was contingent on the purpose of the building, the buildings orientation, local climate and finances (table 3.3). The religious order may also have determined the type of glazing used – or perhaps not used, for example, in the 12th century figurative and coloured window schemes were prohibited in

Cistercian monasteries. However, the resultant predominantly monotone grisaille schemes of the 12th century to early 14th century, were not exclusive to the Cistercian order as they were functional and cheaper than pictural schemes and thus were also installed in Benedictine monasteries.

The following table (table 3.3) provides an overview of the glazing of the main buildings in the monastic range

Table 3.3 Overview of the glazing of the main buildings in the monastic range

Building	Glazing	Reference
Church	The church was the most important building in the complex. Glazing provided a practical light for everyday tasks and an ethereal light that combined colour and imagery. Huge windows in the east and west ends, and clerestory lights in south and north sides brought light into the body of the church. Donor windows are most likely to have been installed in the church, and the donor was often depicted on the window either in name or as an image, sometimes shown offering the gift of the window itself (Marks, 1993, frontispiece).	Fletcher, p.333
Chapter House Library Scriptorium	The buildings were south facing to utilise the best natural light and glazed with uncoloured plain glass or monotone grisaille schemes, for example at Rievaulx	Cook, 1960, pp. 20–21
Frater	Elevated windows on the south wall were installed to maximise natural light	Lillich, 1985
Chapels	Glazed, pictorial windows, for example at Bordesley gatehouse chapel (this study)	This project
Cloister	Glazing appeared in the 13th century although it was not common until the 15th century. Durham Cathedral cloister was glazed, but here the cloister was also used as the scriptorium; also found at Westminster, Bury St Edmunds, Peterborough. At the Dissolution, the 15th century cloister walk windows from Dale Abbey were installed (translated) in St Matthew's Church, Morley, Derbyshire. Documentary records show the sale of the cloister windows from Bordesley Abbey	Hayward, 1973, p. 93; Willmott, 2020, p. 44; Platt, 1984
Infirmary	Possibly grisaille to maximise natural light, with example at Chartres Cathedral	Lillich, 1985
Abbot's lodgings	The glazing could be quite elaborate depending on the abbot's taste and the finances of the monastery at the time of glazing, for example at Hyde Abbey (this study). Archaeological evidence from Glastonbury Abbey show that the lodgings were remodelled and updated over time	Platt, 1984, p. 210)

3.9 The Dissolution of the Monasteries

The Protestant Reformation of the 16th century was a religious reform movement in Europe that challenged the authority of the Pope. England broke with Rome in 1534 with the Act of Supremacy that declared Henry VIII head of the Church of England. A major consequence of the Reformation was the Dissolution of the Monasteries between 1536 and 1540. There had been gradual dissolution and closure of monasteries from the late 13th century when alien priories, which were those under the direct control of continental mother houses, had been seized or transferred to other orders (Willmott, 2020, p. 16). For those monasteries that were not repurposed at the Dissolution, the physical process of their dismantling was a means of destroying the religious institutions and raising capital for the crown in the process. It was also symbolic of the break with the Catholic church and the establishment of the new Protestant order: of 'effecting a physical and institutional break with the past' (Aston, 1973, p. 231).

3.9.1 The process of dissolution

Once surrendered, the process of dismantling the monastic buildings at most sites was orchestrated swiftly and professionally undertaken, 'plucked down' by crews of demolition workers (Platt, 1984, p. 227). After the removal of the portable wealth such as plate and jewels, which were retained for the Crown, other materials were salvaged including copper alloy from the bells, ashlar facings and stone mouldings (Willmott, 2020, pp. 29, 33). Lead from the roof was stripped, melted down, then cast into large ingots to be transported off site. Archaeological evidence of furnaces and hearths demonstrate that lead melting was undertaken on site and often inside the monastic buildings themselves, for example, in the church at Sopwell Priory, Hertfordshire (Willmott, 2020, p. 27) and in the refectory at Alcester Abbey (this study) (Minutes, 1939, Birmingham Museum Archives). Furnace men are known to have been employed for the specialist job of building the furnace or hearth, undertaking the melting and forming the portable lead ingots (Aston, 1973, p. 239). Water damage accelerated the collapse of the roofless buildings, and some materials, particularly masonry, were salvaged and sold. The standing remains, which are visible today at Whitby and Rievaulx abbeys are evidence that a complete clearance was not always necessary 'to wipe out forever a whole department of religious life' (Aston, 1973, p.231). Most sites were then sold or leased to new private owners.

3.9.1.1 Glass and the process of dissolution

As with the retrieval of the lead from the roof and the bells, so the retrieval of the lead cames from the window installations was carried out, either at the first stage of dismantling or post-dissolution after the site had been leased or sold to a third party (Willmott, 2001, 48). As described earlier (section 3.1), windows (glass and associated lead) at Rievaulx Abbey were sorted into three grades (Fergusson, Harrison and Coppack, 1999, p. 180, 229). Experienced glaziers were employed for the careful removal of the more desirable and valuable windows (grades one and two) (Willmott, 2001, p. 47), Generally, the first-grade glass was the newer

more fashionable glazing schemes that were retained for the crown's use, thus for example, workers were instructed to remove the west window from Rievaulx and store the glazing at the crown-owned Helmsley castle (Willmott, 2001, p. 46). The second grade we are told was to be sold, while the third-grade windows were important only for the value of the lead came, and the window glass being of no value, was dumped. It is most likely this dumped 'third-grade' glass that forms the research material used in this study.

3.10 Summary of background history

The social, economic and religious background to the 12th century to 16th centuries provides a context for the study of excavated window glass from monastic sites. This glass was deposited during the Dissolution of the Monasteries when window glass probably of the 'third grade' was stripped of its lead and effectively thrown away. Some of this window glass was retrieved from the seven study sites during 19th, 20th and 21st century excavations and selected samples form the basis of the study material. The following chapter summarises the main stylistic developments in applied window decoration in the medieval period.

Chapter 4

4. The development of decorative styles in window glass

4.1 Introduction

It is possible to chart an evolution within the decoration of medieval window glass from the brightly coloured biblical windows of the 12th century, through the monotone grisaille schemes of the 13th century, to the depiction of characters in architectural contexts of the 14th and 15th century. It is a complex picture, with coexisting styles and decorative elements sometimes spanning many centuries. Excavated fragments of window glass can nonetheless be dated by judicious comparison with decorated in-situ windows of a known date, and it is possible to create a temporal framework using the dates of the glasses that have been established in the study, to investigate the consumption of the glasses at the high-status monastic sites over time.

This chapter maps the main decorative styles that were used for decorating window glass in the medieval period and discusses the glass painting process and the organisation of the glazier's workshop. This forms the initial basis for dating the glass for subsequent analysis.

4.2 Traditional dating techniques

Medieval windows can be dated through an art history approach by comparing the motifs and patterns painted onto the glass with those on in-situ windows of known dates. As with painting, architecture and clothing, fashions also changed with stained glass windows. Design details and colours popular in the 13th century for example, were supplanted with a different range of design details and colours in the 14th and 15th centuries, albeit with periods of overlapping. Many details from everyday life were depicted in the contemporary style, thus, architectural elements, and details such as the shape of a hat or a tunic worn by a figure that reflected the fashion of the day, were taken from the contemporary style. (Crewe, 1987, p. 63).

Through research undertaken by glass scholars including P G Westlake in the 19th century (e.g. 1879), Madeline Caviness (e.g. 1996) and Peter Newton (e.g. 1989) in the 20th century, and Pam Graves (e.g. 2000) and Meredith Lillich (e.g. 2001) in the 21st century, a chronology of the painted motifs and designs, colours and techniques that were used to decorate windows has been developed. Repositories of dated reference material are available in books such as Corpus Vitrearum Medii Aevi (CVMA) county volumes on stained glass and Westlake's History of Design in Painted Glass (Westlake, 1879, 1882), and online sites such as CVMA (cvma.ac.uk), Visual Arts Data Service, (VADS) (vads.ac.uk/digital/collection/CVMA) and The Rose Window

(therosewindow.com). The dating of excavated fragments can be achieved by matching their painted decorative details with similar details on extant, in-situ windows of known dates. These are called dated parallels. Dated parallels can also be used to help imagine the type of glazing scheme or schemes represented in an assemblage of excavated window glass. This is explored using samples from the study (Appendices 19-25).

4.2.1 Dating difficulties

There are always difficulties in dating excavated glass using dated parallels. Some excavated fragments are painted with decoration that was used for a long period of time (referred to as a long date range) - open beading for example, which is a motif of repetitive circles often used in borders and was popular from the 12th to the 14th century. Dating such glasses can, however, be determined by aligning with precisely dated decorated samples of a similar chemical composition or by looking at the overall assemblage and estimating the date. This can also be applied to undecorated fragments and indistinct motifs that are worn, flaky or too small to be determined. Some assemblages contain glasses where the stylistic and compositional dating are incompatible and the glasses are probably later inserted patches painted to match the original scheme, to replace a damaged windowpane (Marks, 1993, p. 39).

Windows were also repainted, rearranged, or patched with plain glass or substitute glasses taken from other windows. Freestone et al. (2010, p. 10) suggest that glaziers kept coloured glass in stock for replacement glasses, and it is known that warehouse stocks of imported coloured glass were requisitioned for the glazing of the royal chapels in 1351 (Knowles, 1922, p. 343). Although difficult to detect in an excavated assemblage, replacements and patches can be observed more easily in extant windows, and examples are found at Lincoln Cathedral where evidence from written sources demonstrate that some medieval panels were gathered together in the 18th century from multiple windows (for example n.XXVII, CMVA 000233) (figure 4.1) (Morgan, 1983, p. 1). A 1970s example of a rearranged window is at St James the Great, Castle Acre in Norfolk (CVMA 010848) (figure 4.2) (Bowman, 2025. Telephone conversation, 20 May) and at York Minster a typological study shows that the 14th century St John window (s.XXXI) is patched with plain glass (therosewindow.com). Further studies using portable X-ray Fluorescence (pXRF) have also found windows made up of fragments of different dates, for example at Winchester Cathedral (Dungworth, 2019, p. 131). It is noted that repainted glass may have a different paint colour or have been painted in a different style to the original. Glass was also repaired, for example using shellac to consolidate broken or cracked glass, for instance at Whitby Abbey this project (W18 and W20) (see section 7.8.3).

Figure 4.1 Lincoln Cathedra, n.XXVII (CVMA 233). Composite window of mostly 13th century fragments gathered together in the 18th century. Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

Figure 4.2 Composite window at St James, Castle Acre, Norfolk, rearranged in the 1970s (CVMA 10848), Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

4.3 Decoration ideas, influence and dissemination

The motifs and designs used in stained glass windows resembled the designs seen in artforms including sculpture, wall paintings and metalwork (Hogan, 1940, p. 580) - Westlake refers to techniques used to model facial features as having been taken from sculpture (1879, p. 8) and Deuchler (1989, p. 122) refers to the influence of manuscripts on stained glass design. Overall, stained glass windows reflected contemporary tastes, which might be regional: a common repertoire of motifs is seen across architectural and ornamental design (Marks, 1993, p. 55), for example, the grotesques and drolleries seen in the borders of decorated windows in the 14th century, which were derived from the bas-de-page (margins) of manuscripts, are at the same time seen on the decorated floor and wall tiles, and sculptural stonework of churches and monasteries (figure 4.3); and likewise, the simple trefoil leaves seen in stiff leaf grisaille windows were also used for sculptural elements (figure 4). The portability of manuscripts (such as the Queen Mary Psalter MS (Crewe, 1987, p. 52) and of block books containing ideas for window designs and motifs helped facilitate the dissemination of decorative ideas in the medieval period (Brown, 2019, p. 12) (see section 3.7).

Figure 4.3 Carved stonework retrieved from Bardney Abbey depicting a grotesque similar to those used in decorated windows. Photograph by B Stone (author)

Figure 4.4 Architectural stonework at Rievaulx Abbey showing a carved trefoil similar to those found in the 13th century stiff leaf grisaille window schemes at the abbey (see section 7.7.1). Photograph B. Stone (author)

In carefully planned glazing schemes such as at Canterbury Cathedral, windows were arranged thematically: Prophets from the Old Testament were seen on the north side, subjects from the New Testament, for example the Apostles, were on the south side, and the west window often contained figural depictions of saints and religious leaders. The windows were also designed to be read left to right and, strangely from a 21st century perspective from bottom to top (Deuchler, 1989, p. 121). However, iconographical programmes were rarely presented coherently, and this is especially so in a monastery since building and glazing was undertaken piecemeal and the re-use of glazed panels and their movement around a building was not unusual (Marks, 1993, p. 40, 64). This may have occurred with the commissioning of a new window or the remodelling of the monastic range as fortunes changed, for example as the community adjusted to a declining membership (for example at Bordesley (see section 5.5.3)).

4.4 Chronology of decorative styles

This section describes the chronology of decorative styles and techniques used in decorated glass that can be broken down into broad, simplified categories relating to each century from the late 12th to the early 16th centuries for ease of understanding.

4.4.1 Late 12th and 13th century

Two contrasting styles of decoration were used by glaziers in the late 12th and 13th centuries; these are biblical themed narrative windows and grisaille.

Biblical themes

The survival of early 12th century glass is rare, but from extant windows, for example at St Michael, Dalbury (c. 1100-35), it can be seen that the decoration is stiff and formal (Marks, 1993, p. 112). By the late 12th/early 13th century decoration had become more naturalistic and flowing, as demonstrated in the Genealogy of Christ series and the Becket Miracle windows at Canterbury Cathedral (Michael, 2019, p. 32, 102), and was often accompanied by script in the Lombardic style. Biblical themed narratives were arranged across several panels, sometimes as medallions enclosed by geometric-shaped borders. The individual panes of differently coloured glass were cut (grozed) to represent, for example, different parts of the body or different background features. Such figures and simple architectural elements were created in strong bright colours including red, green, yellow, murrey (pink/purple) and blue (for example, The Sower, Canterbury Cathedral, n.XV panel 8; Baker, 1978, pl. 6) (figure 4.5).

Figure 4.5 Baker, 1978 pl. 6, The Parable of the Sower, 13th century

These colours were highly symbolic, red for instance represented the blood of Christ, the Catholic Church, power and martyrdom, and blue symbolised the divine, godliness and the Virgin Mary. The use of purple as a symbol of power, royalty and opulence is widespread and dates from at least the 1st century AD (St Clair, 2018, p. 159), and was widely used in medieval glazing, for example, Herod and the Magi from the Typological window at Canterbury Cathedral (n.XV) (Michael, 2019, pp. 52–53).

Grisaille

Grisaille was a decorative style in use from the 12th to the 14th century. Its name is derived from the French meaning 'greyed' due to the appearance of the overall monotone scheme that used black or brown paint on predominantly uncoloured glass. There are two basic grisaille patterns, geometric, and ornamental or stiff leaf. Geometric grisaille uses individual unpainted colourless quarries simply arranged in inter-lacing bands that are formed by the lead came. Its simplicity and repetition symbolise clarity, order and eternity. Its use in England was however, limited, a relatively rare example is in Salisbury Cathedral (1220-1258) (Marks, 1988, p. 215; Westlake, 1879, p. 136, 139). It was however frequently combined in a window with stiff leaf grisaille often in a complex arrangement (Zakin, 1974). Conversely, stiff leaf grisaille was very common in monastic glazing in England until the end of the 13th century. It comprises painted foliate motifs particularly that of the trefoil. This motif was based on the lily and appears stylised and painted in a thick, continuous outline. The lily was an important motif in the medieval period as it was associated with truth, order and the Holy Trinity (Channen Caldwell, 2014, p. 1). Subtle variations that developed during the 13th century include the quatrefoil and multi-foil, side branching and double-headed trefoils, straight and twisting stems, spurs, and berries hanging from the trefoil head. Early to mid-13th century grisaille is characterised by a cross-hatched background (table 4.1) (see examples from Salisbury Cathedral (CVMA 9954) figure 4.6 and Westwell (CVMA 7386) figure 4.7 below).

Grisaille emerged through the teachings of the Cistercian St Bernard of Clairvaux. In 1134 he prohibited the use of figurative and coloured glass in Cistercian windows, which were considered a distraction for the contemplative Cistercian monks (Graves, 2000, p. 505; Allen, 2009). Grisaille was not exclusive to the Cistercian order however, and grisaille window schemes in England include Five Sisters at York Minster Salisbury Cathedral Canterbury Cathedral (Benedictine until the Dissolution) (Hayward, 1973, p. 94). Grisaille was used to bring more natural light into a space, plus they were also more affordable than full-colour pictorial schemes and glazing could be completed quickly (Woodforde, 1954). By the early 13th century, the aesthetic ideals of St Bernard had become more relaxed; coloured quarries were interspersed throughout the window and grisaille motifs were incorporated into the borders of pictorial windows, for example at West Horseley Church, Surrey (1210-25) (Brown, 1999, p. 88). By the end of the 13th century and into the early 14th century, grisaille was used alongside coloured panels in band windows.

Figure 4.6 Illustration of a stiff leaf grisaille design from Salisbury Cathedral (CVMA 9954), Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

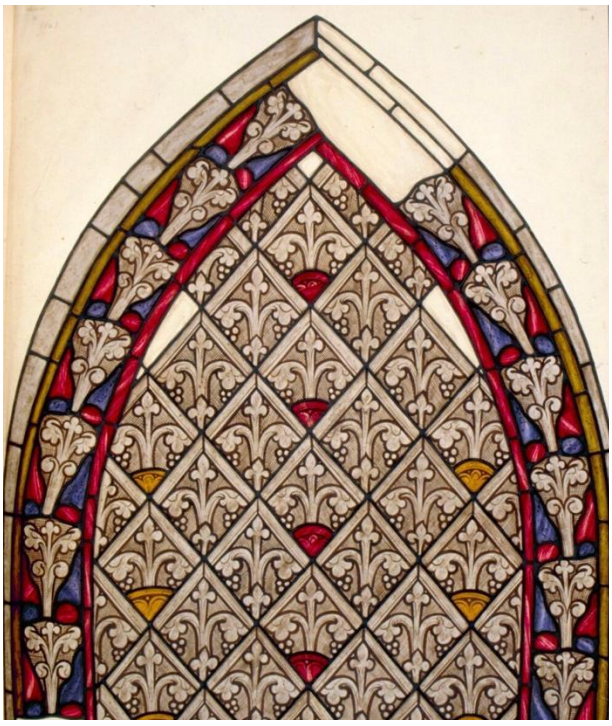


Figure 4.7 Illustration of stiff leaf grisaille window from Westwell (CVMA 7386), Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

4.4.2 Late 13th to early 14th century

About the same time, the classical motifs of the 13th century such as the lily were gradually replaced with natural forms such as oak, ivy and maple leaves, as well as exotic fruits such as pineapples, which were set within interlacing trellis or strapwork. This is termed naturalistic grisaille, in which the painting is finer, and the cross hatching and thick outlines that characterised stiff leaf grisaille had been abandoned (Westlake, 1879, p. 136) (table 4.1). This style crosses over into the 14th century so most glasses with naturalistic motifs are dated 13th/14th century, and the use of naturalistic grisaille continued until around 1330, for example at Waterperry, Oxfordshire (CVMA 5222) (Graves, 2000, p. 375) (figure 4.8). The finest examples of naturalistic grisaille are York Minster Chapter House dated to the late 13th century (Marks, 1993, p. 147) and Merton College, which was installed 1305-11 (Ayres, 2013).

Table 4.1 Grisaille Motif with associated stylistic detail

Date	Grisaille Motif	Stylistic detail
C13 first half	Trefoil	Upright and curling leaves, some double-headed, side branching trefoils, flanking leaves, short or long spurs (where head joins stem); may have split, straight and twisting stems
	Berries	Single to multiple hanging from side-curling foliage
	Veins and stamens	Thin painted internal lines
	Strapwork	Bordering painted lines of varying thickness
	Background	Cross hatching
C13/14, until c.1330	As above but plain background,	Smaller and curling trefoil gradually replaced with, for example, ivy and oak and maple leaves
	Quatrefoil	Pointed or rounded lobe
	Stamens	Cross lines, tear shapes in reserve between lobes
	Strapwork	when joined appears as a trellis Some strapwork with curved edges
	Naturalistic forms: acorn, oak leaves, lily, rosebud, plain ground	Drawn in outline, double vein, sometimes dots under leaf edge
	Stem	Serpentine line

Figure 4.8 Naturalistic grisaille at Waterperry (CVMA 5222), Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

4.4.3 14th century

It was during the 14th century that painted window glass really reached its medieval zenith. Woodforde (1954, p. 9) regards the window glass decoration of the first half of the 14th century as having 'reached its greatest beauty of colour and design', citing Eaton Bishop Church, Hereford (c. 1317-21) (figure 4.9) and the Great East Window at Gloucester Cathedral (c. 1350) as the finest examples of 14th century glazing. Marks (1993, p. 166) describes decorated window glass produced between 1350 and 1380 as 'an anti-climax' after the achievements of the earlier period. One of the main design themes of this period was of a figure such as a saint placed under an architectural canopy. Such figures were subtly modelled with delicate facial features and often standing in the 'S' shaped pose that characterised much medieval figurative art (vam.ac.uk/articles/the-gothic-style-an-introduction). An increased range of colours was employed including yellow, orange, green, and earthy tones that reflected the increased interest in the natural world. Some of the colours were created using silver stain and as such fewer differently coloured panes were needed to make up a panel since multiple colours could be created on the same quarry. Westlake (1882, p. 99), Crewe

(1987, p. 23) and Marks (1993, p. 154) describe the chronology of many of the figurative details and decorative motifs of the 14th century, some of which are tabulated below (Table 4.2 and table 4.3)

Figure 4.9 East window, Eaton Bishop (CVMA 14727) Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

Table 4.2 14th Century design elements

C14 Figures	Design element
Drapery	Flowing, longer, larger folds
	Gathered at waist and tight at wrist
	Cloak cascades
	Lining in different colour
Fabric	Diaper patterns
Shoes	Pointed
Figure	Slender, elongated, 'S' shaped, used for artistic balance (Marks, p. 170; vam.ac.uk, 2025)
Heads	Quainter and characteristic e.g. Fladbury (CVMA 2888)
Hair	Men: concentric circles, curled inwards, forked beards (Marks, p. 170)
Face	Lips pouted, heavy brow (Marks, p. 170)
	Eyes dot and flick, accentuated (Marks p. 170)
Accessories	Scrolls with name of donor
Armour	Plated gradually replaced chainmail in the second half of the C14

Architectural canopies were rendered in the contemporary style, for example in the use of crockets, mouldings, and pointed and ogee arches. Repeating foliate motifs (diaper and rinceau) were used in the background and a variety of zoomorphic and vegetal species, and the drolleries and satirical scenes that are mentioned above filled the borders. Some examples are listed in table 4.3

Table 4.3 Some examples of 14th century border motifs

Borders	Motif
Patterns	Serpentine and straight, beaded
Vegetal	Leaves, fruit, ivy, oak
Animals	Grotesque, drolleries, lions, monkeys, birds, hybrids
Heraldic	Coats of arms, initials, fleur de Lys
Religious	Angels

Passages from the bible often accompanied figurative scenes using black Gothic script, which had mostly superseded Lombardic by the second half of the 14th century (Marks, 1993, p. 167). The juxtaposition of saintly figures and grotesque, demonic creatures was influenced by the block-book, *Ars Moriendi* (see section 3.7) and was a common theme aimed to emphasise the battle of goodness against evil. Other motifs included moths and butterflies that were used to symbolise the transience of life, which, along with skeletons, corpses and the dead rising were popular themes following the Black Death (Marks, 1993, p. 80-81, 167).

Donors

The donor was significant in the 14th century for funding and determining the design of windows, many of which were installed in prominent buildings such as the church (e.g. Marks,

1993, p. 3-27; Crewe, 1987, p. 31-37). Heraldry featuring their coats of arms and heraldic beasts such as the lion rampant were deployed; examples include the Peter de Dene window at York Minster, dated 1306-10 (CVMA 011874) (figure 4.10) and windows in the north-east clerestory of the apse at Tewkesbury Cathedral, dated around 1338-40 (CVMA 001958) (Crewe, 1987, p. 37). Such devices were chosen to reinforce the image of the donor as noble or courageous. Donors themselves were also depicted on the window often holding scrolls and architectural models in order to emphasise their contribution. The donor window at St Denys, York (c. 1340) shows the donor, Robert Skelton offering a scaled model of the window against a background of repeated, single quarries of moth motifs (Marks, 1993 frontispiece; CVMA 18486).

Figure 4.10 Peter de Dene window at York Minster, dated c. 1306-10 (CVMA 11874) , e. C14 Corpus Vitrearum Medii Aevi (2025). York: Archaeology Data Service [distributor] https://doi.org/10.5284/1132566

Aftermath of the Black Death

In the aftermath of the Black Death in the second half of the 14th century, window decoration was dominated by colourless and silver stained glass particularly in the form of single diamond-shaped quarries with repeated, individual motifs (Westlake, 1882, p. 102). The drolleries that had characterised the borders of windows painted in the first half of the 14th century were largely replaced with silver-stained heraldic devices and large individual letters. Silver stain was instrumental in depicting some of the more complex heraldic devices that would otherwise have been difficult to construct using individual coloured quarries (Baker, 1978, p. iii). Figures set within architectural canopies continued to be employed although the palette was limited, in particular to the earthy tones created using silver stain, from lemon-yellow to deep orange, almost ruby, and brown (Baker, 1978, p. ii).

4.4.4 15th century

In the 15th century there was a resurgence in religious belief and devotion, and from around 1440 an explosion in church building and monastic improvements (Ziegler, 2008, p. 276; Byng, 2017, p. 14). Accordingly, window design depicted biblical events, the lives of the Saints and scripture using black Gothic script. Tracery constructed in the new Perpendicular style was taller than the previous Decorated or Early English styles, and thus figures were shown under heightened architectural canopies (see section 3.8.4). These scenes appeared three dimensional through the use of decorative effects such as stipple shading (see glossary) and the widespread use of silver stain to colour and highlight for depth and detail. Blue and red glass was used sparingly to colour background diaper and seaweed patterns. Whereas skin tones had previously been in hues of brown and murrey, by the start of the 15th century, heads, feet and hands were exclusively white (using uncoloured glass) (Westlake, 1882, p. 2). Drapery was more angular, with heavy swathes and fewer folds (Marks, 1993, p, 174). (Table 4.4)

Table 4.4 15th century design elements

C15 decoration	Design element
Lettering	Black Gothic (continued use from the mid C14)
Micro-architecture	Heightened architectural canopies because of taller Perpendicular windows
Figures	More angular drapery and fewer folds, uncoloured glass replaced murrey for skin tone, characteristic faces (e.g. by John Thornton)
Subject matter	Biblical scenes, the lives of the saints
Style	3D effects, stipple shading and silver stain, sometimes thick outlines
Colours	Red and blue but used more sparingly; the range created using silver stain, yellow, orange, brown
Background and borders	Local vegetation and seaweed diaper

During the 15th century regional and workshop styles developed, for example York and Norwich, where 'schools' of glaziers emerged that decorated their glass in a similar style (Woodforde, 1954, p. 161). Regional designs included presentations of localised vegetation and animals, for example ears of barley in East Anglian windows (Marks, 1993, p. 185). Such motifs were depicted in borders and as decorative detail on clothing. Faces in particular exhibited workshop traits, for example the thick outlines and defined shading executed by emigres from the Low Countries working in York in the 15th century who were much influenced by Dutch and German woodcut prints (Hogan, 1940, p. 580; Baker, 1978, p. ii). John Thornton also, working around the Midlands and in York in the early 15th century, had a notable style of painting faces with small mouths and long noses with a bulbous tip (Marks, 1993, p. 183) (figure 4.11). This contrasts with 14th century facial styles, which are generic, or 'conventional' and unable to be ascribed to a particular region (Westlake, 1882, p. 3).

Figure 4.11 panel 1e, Bishop Walter Skirlaw, Great East Window, York Minster (Credit http://www.yorkglazierstrust.org/about-us/case-studies/york-minster-great-east-window/)

4.5 Glass painting

The production of each medieval stained-glass window began with a sketch of the window design, a vidimus, from which a full-size drawing was created called a cartoon. Theophilus describes how the cartoon was drawn straight onto a whitewashed glazier's table (Hawthorne and Smith, 1979, p. 61). An example of a surviving glaziers table is from Gerona Cathedral dated to around 1340 (Brown, 1994, p. 19). The drawings were undertaken by the master glazier, or a professional draughtsman or limnour (an illustrator or illuminator of manuscripts) (Crewe, 1987, p. 13; Marks, 1993, p. 25). Paper, which was cheaper and reusable, was used from the late 14th century in Italy, and by the mid-15th century in England (Brown, 2014, p. 25; Marks, 1993, p. 34). The lead came lines were drawn in and the glass was then cut to shape. A hot iron was used to break the glass into the general shape required which was then refined to the exact shape using a grozing iron (see glossary) (Crewe, 1987, p. 10). The individual pieces of glass are called quarries.

Details such as hair, facial features and architectural elements were painted onto the glass using paint described by Theophilus as a mixture of powdered glass, copper filings or lead combined with a solution of wine or urine (Hawthorne and Smith, 1979, p. 63). To this was also added a binder such as gum arabic. Paintbrushes were made of badger, squirrel, hog or cat brush. (Marks, 1991, p. 273; Brown, 1994, p. 24). The individual quarries were then fired in a kiln at 650-700°C to fix the paint onto the glass and then annealed. Additional painting, shading or stickwork was applied to add depth and detail to the decoration (see glossary).

Silver stain was used from the early 14th century to add colour and highlights to the glass, and the first datable window using this technique is York Minster, window nXXIII (TPQ 1307-12) (Marks, 1993, p. 154). It was made from silver filings mixed with an ochre binder and painted onto the back of the quarry (Delgado et al., 2011, p. 2383 ; Brown, 2019, p. 17) (see 4.4.3, above). Silver stain was expensive to use and until the later 14th century was used only sparingly, for example on figures and canopies (Westlake, 1882, p. 99).

Once the quarries had been painted and fired, the panel was assembled using strips of malleable lead with an H-shaped profile to fit round each quarry (cames) and was then sealed using cement or chalk. The panel was strengthened with iron armature before being fitted into a rebated wooden frame in the window opening or grooves cut into the stone tracery (Brown, 2019, p. 101).

4.5.1 How a workshop operated

By the 13th century there were glass painting workshops set up in towns and cities such as York and Lincoln, with some peripatetic glass painters also moving between commissions such as churches (Woodforde, 1954, p. 8; Marks, 1993, p. 41). Glass painters' guilds were established in England in the 14th century, the London-based Company of Glaziers for example,

was established by 1328 (Ashdown, 1919, p. 16). The role of the guild was manifold, but one responsibility was to regulate the workforce; accordingly, a glazier's workforce was small and consisted of a master glazier, one or two apprentices and a journeyman who was a qualified glazier but not master of his own workshop. For large glazing orders workshops combined forces (Marks, 1993, p. 43-44). Documentary accounts for the glazing of the chapel of St George at Windsor in the mid-14th century for example, list a workforce comprising ten glass-painters, sixteen cutters and glaziers, a boy for grinding colour and a labourer who kept the fires going for heating the soldering irons (Knowles, 1922, p. 345). This document demonstrates the specialist roles involved in glazing and the division of labour. Many glaziers workshops were family businesses and in York for example, a network of workshops was run by inter-related families (Marks, 1991, p. 277, 279). This meant that the control of business was restricted to a small group of people with the same vested interests in a similar manner to the kinship network of the glassmakers. In the late 14th century and into the 15th century however, the shortage of glass painters after the Black Death meant that for some of the larger commissions glaziers from a wider area were seconded. Master glazier John Thornton came from Coventry for example, to create the Great East Window at York Minster (1405-08) (Knowles, 1922, p. 348).

It was difficult for glaziers from abroad to establish workshops in England because of the restrictions put in place in the late 14th century by the guild system. It is likely, therefore, that even if the glass used was imported from the continent, the glass painters would probably have been local or at least English. There are examples of Flemish glaziers establishing workshops in Norwich during the late 15th century and in Southwark by the early C16, although by this time the power of the guilds had weakened (Marks, 1993, p. 42-44). This was due in part to the changing market and government intrusion (Epstein, 1998).

4.5.2 Contract

A contract between client, who in a monastic glazing scheme was the abbot or a donor, and the glazier stipulated the subject matter of the window design, the timeframe for completion and the budget. Glazing schemes were priced by the foot or for the whole scheme (Knowles, 1922, p. 346; Marks, 1993, p. 31). A contract might also dictate the source of the glass, for example in the mid-15th century, John Thornton was instructed by the Dean and Chapter of York to buy the highest quality imported glass for the glazing of Beauchamp Chapel in St Mary's Church, Warwick. The contract also explicitly forbade the use of English glass (Crewe, 1987, p. 13). Glaziers were also, at times, responsible for sourcing the glass and they were aware of, for instance, the different colours and quality of glass available (Brown, 2019, p. 10). In 1470 for example the glass painter's guild of Antwerp stipulated that its members use only high-quality Norman crown glass and to a lesser extent, German glass (Caen, 2009, p. 236). However, Caen also identifies that the Dutch glass painters' guilds in the 16th century were 'out of touch' for not understanding the fashion for undecorated and colourless glazing.

4.6 Summary

Dating the excavated glass as tightly as possible is an important aspect of this research project as it provides a temporal framework with which to examine the consumption of window glass at each site. An understanding of the evolution of decorative styles helps date a decorated fragment of glass. This is enhanced through an appreciation of the context of the glaziers work, how a window was made up of multiple quarries of different shapes, colours and decoration, and that this changed over time. The following section introduces the study sites, describes their religious, economic and geographical backgrounds, details the archaeological interventions, and provides a summary of the glass fragments used in the study.

Chapter 5

5. Sites and samples

5.1 Introduction

The material for this study comes from seven monastic sites of two contrasting orders, Benedictine and Cistercian, from four different areas of England: North Yorkshire, Lincolnshire, the West Midlands, and the south coast. The areas are distributed to allow for a comparison of glass consumption from regions with proximity to different glassmaking centres in England and continental Europe, and transport networks. The selection of window glass from both Benedictine and Cistercian abbeys, with one of each in each area, allows for a comparison to be made of glass consumption between contrasting monastic orders. The sites are Whitby Abbey and Rievaulx abbey in North Yorkshire, Bardney Abbey and Louth Park Abbey in Lincolnshire, Alcester Abbey and Bordesley Abbey in the West Midlands and Hyde Abbey, close to the south coast, where there is one Benedictine abbey (fig 5.1).

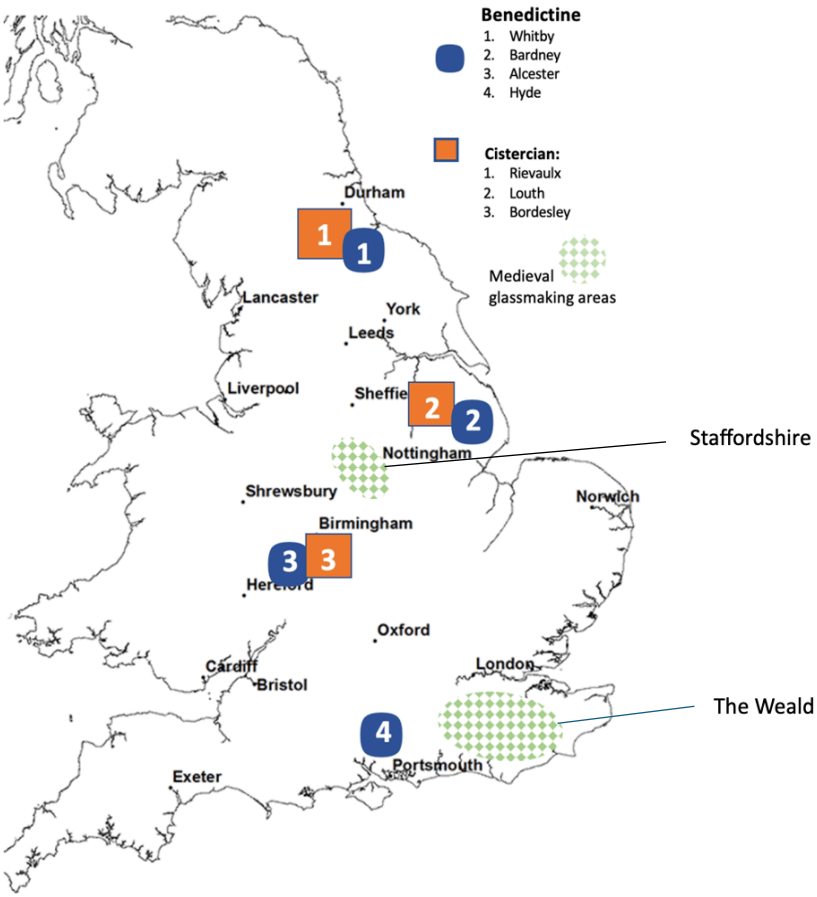


Figure 5.1 Location of the seven monastic sites that form the basis of this study, showing Benedictine sites (blue) and Cistercian sites (orange). Also featured are the two main medieval glassmaking areas that are known in England, the Weald and Staffordshire

The chapter provides contextual information about the seven abbeys in the study. It begins with a summary history, describing the foundation, source of wealth and fluctuating fortunes of each of the abbeys. Each of the four geographical areas where the abbeys are located is then discussed with respect to the trade routes and proximity to glassmaking areas, and this is followed by a description of the archaeology of each site and an assessment of each assemblage of window glass.

5.2 Foundation and patronage

The abbeys were founded in the 11th and 12th centuries (table 5.1). Most of the Benedictine abbeys in the study were connected to Anglo-Saxon cathedrals: Whitby was built on the site of an Anglo-Saxon monastery (Atkinson, 1894, p. 107), Bardney was founded as a cell of Abbey de Charroux in France on the site or in the vicinity of an Anglo-Saxon abbey (Harrison, 2012, p. 2) and Hyde was a result of a move to Hyde of the Old Minster in Winchester, which was the Anglo-Saxon cathedral (Cook, 1960, p. 54). Alcester was founded by benefactor Ralph le Boteler of Oversley (Clark, 1997, p. 4). The Cistercian abbeys were founded through a system of expansion by spurring off from existing Cistercian abbeys that all had lineage to the motherhouse at Citeaux in north-central France. In this manner, the number of Cistercian monasteries in England grew rapidly, particularly in the north (Lawrence, 2001, pp. 183–185).

Table 5.1 Summary of the abbeys in the study showing religious order, and details and date of their foundation

Monastic order	Site	Date of foundation	Patronage
Cistercian	Rievaulx	1132	Daughter house of Clairvaux and granddaughter of Citeaux in France
Benedictine	Whitby	1078	Granted the site of former Anglo Saxon monastery by Lord William de Percy
Cistercian	Louth Park	1139	Daughter of Fountains Abbey and granddaughter of Citeaux
Benedictine	Bardney	1087	Originally an Anglo-Saxon abbey, re-founded as a cell of Abbey de Charroux in France but became independent in 1116
Cistercian	Bordesley	1138-40	Granddaughter house of Waverley Abbey, whose mother house, L'Aumone Abbey in Normandy had lineage to Citeaux
Benedictine	Alcester	1138	Founded by Ralph le Boteler of Oversley
Benedictine	Hyde	1110	Relocation of Old Winchester Abbey

5.3 The monastic economies

As shown in table 5.2, there is evidence that all abbeys received grants and donations to establish their foundation. Whitby's initial wealth, for example, was derived from donations and land holdings from as far away as York and Middlesborough (Clark, 1997, p. 10). By the 13th century, at Rievaulx, Bardney, Bordesley and Louth Park income was also generated from sheep farming; Rievaulx especially grew wealthy using granges and lay brethren to farm.

Table 5.2 Summary table showing the fluctuating fortunes of the abbeys, showing Income, prosperity and wealth coloured in green, and periods of poverty and debt coloured in red

Site	12th & 13th century	14th century	15th century	16th century
Rievaulx	Initial grants then great wealth from wool and output of granges and an iron works at the abbey	Losses in wool market at end of 13th century	Buildings remodelled	
Whitby	Donations and land	Debt, use of fabric fund and fundraising	Great West Window reinstalled	
Louth Park	Land and endowments, income from wool. Period of debt in early 13th century, new abbot, Richard of Dunholme revived prosperity	End of 13th century-early 14th century in debt from wool market crash	Plague epidemic in abbey	
Bardney	Considerable endowments and donations since the 11th century foundation, subsequent income from wool sales.	Competition for patronage in Witham Valley resulted in Impoverishment.	Continued debt, sale of assets	
Bordesley	A royal house, received grants and gifts; income from farms and granges farming sheep for wool	Around 20 granges Shifting patronage, debt	Improved finances, reconstruction of abbey buildings	
Alcester	Tithes and rent, endowments, extensive lands	Maladministration, extreme poverty.	Poverty, absorbed and downgraded to priory	Endowments, range rebuilt in 1515
Hyde	Prosperity, gifts, endowments, income probably from pilgrimage	Abbey in ruins, fund raising	Debt but funds found for rebuilding programme after a fire	

However, during the late 13th century and early 14th century incidents of sheep scab decimated the market for English wool to the continent (the wool trade hit its lowest value around 1335) and all abbeys involved in the business incurred heavy losses (Knowles, 1962, p. 68; Fergusson, Harrison and Coppack, 1999, p. 38–42). Alcester was in debt through the mismanagement of its widely scattered estates (Styles, 1941, p. 38) and Bardney had lost patronage to the new, neighbouring monasteries founded in the Witham Valley in Lincolnshire (Harrison, 2012, p. 3). In the 14th century, all of the abbeys were in debt and the repair of buildings, and the installation of new glazing relied on the fabric fund (a fund designated for the maintenance of the monastic buildings) and fund raising activities to acquire financial aid from benefactors - at Whitby Abbey, for example, alms were collected (Atkinson, 1894, p. 131).

The Black Death in the mid-14th century, with intermittent bouts for the rest of the century, caused the death of monks, lay brethren, and also tenants working on or renting monastic lands. Consequently, income from rents and revenue fell, exacerbating the already dire economic circumstances of the monasteries due to decreased patronage and spiralling costs of maintaining the monastic buildings (Ziegler, 2008, p. 274). Debt continued in the 15th century at most of the abbeys, Alcester, for example, was in such debt that it was absorbed by Evesham Abbey and downgraded to a priory (Styles, 1941, p. 38). Nonetheless, a revival in religious devotion in England and across Europe in the 15th century improved finances for most of the abbeys through increased patronage. This included Rievaulx, where buildings were remodelled to accommodate the much smaller community (Fergusson, Harrison and Coppack, 1999, p. 101); the church at Whitby was completed with the insertion of the west window (Clark, 1997, p. 4); buildings were completed at Bordesley, and at Hyde key buildings were reconstructed following a fire. For Alcester, the early 16th century was a period of rejuvenation when the church was renovated.

By the Dissolution of the Monasteries in the 1530s the size of the communities at the abbeys were significantly reduced. Table 5.3 shows the number of monks resident at each abbey at the Dissolution compared with the numbers of monks from earlier periods (where evidence is available). All abbeys were dissolved between 1536 and 1539.

Table 5.3 The number of monks resident at each abbey at the Dissolution compared with numbers from earlier periods

Site	Date of dissolution	No. at Dissolution	Evidence of community size from earlier periods
Rievaulx	1538	23	C12: 150 monks, 500 lay (Fergusson, Harrison and Coppack, 1999)
Whitby	1538	22	C12: 38 monks 1380: 20 1393: 21 (Atkinson, 1894)
Louth Park	1536	11	C13: 66 monks, 150 lay (Locking, 2022)
Bardney	1538	13	C12–13, >20 (Harrison, 2012)
Bordesley	1538	20	1332: 34 plus 36 lay and hired, 1380-1: 14 plus 1 lay (Astill, Hirst and Wright, 2004)
Alcester	1536	'much diminished'	1444: 'few monks' (Styles, 1941)
Hyde	1539	22	1340s: 30-40, 1350: 29, 1420s: 20, 1488: 24, 1507: 33, 1509: 20 (Gasquet, 1893)

5.4 The study areas: location and connections

The study sites are located in four different areas of England, and this section describes the characteristics of each area in terms of geography, economics, religious heritage and trade links. The map (figure 5.2) summarises some of the transport routes that may have been used for transporting window glass from the ports and English glass production areas.

5.4.1 North Yorkshire: Whitby and Rievaulx

Rievaulx and Whitby abbeys were located in North Yorkshire, around 35 miles apart on the edges of what is now the North York Moors. This was an affluent sheep farming area in the medieval period. Monasteries were established from the 7th century, and by the 12th century a stronghold of eight Cistercian monasteries had been established: initially Rievaulx followed by Byland, Jervaulx and Fountains (which was founded as a Benedictine house and in 1135 became Cistercian). These abbeys were used as a springboard for the colonisation of Cistercian abbeys in the rest of the country (Lawrence, 2001, p. 185). Rievaulx had strong connections with Lincolnshire and founded daughter houses including Revesby and Melrose. (Fergusson, Harrison and Coppack, 1999, p. 43). Benedictine monasteries were founded as centres of learning and spirituality in North Yorkshire. In addition to Whitby Abbey there were also the priories of Wath, Arden, Moxby, Nun Monkton and Selby Abbey (Midmer, 1979).

Although remotely situated in a small valley, Rievaulx was connected to the continent via the river network, using the rivers Rye, Derwent, Ouse and the Humber to ports that included Hull and Filey (Edwards, 1987, p. 143). Inland, the Midlands and Staffordshire were accessible using the River Trent. Whitby Abbey was located on an exposed headland at the port of Whitby and in the medieval period, the east coast of Britain and northwest Europe were easily accessible by boat. Overland, Whitby was accessible by way of a network of Roman and medieval roads that linked Whitby with York, where the glass may have been painted (Edwards, 1987, p. 35). Staffordshire, as with Rievaulx, was accessible via the river network including the Trent.

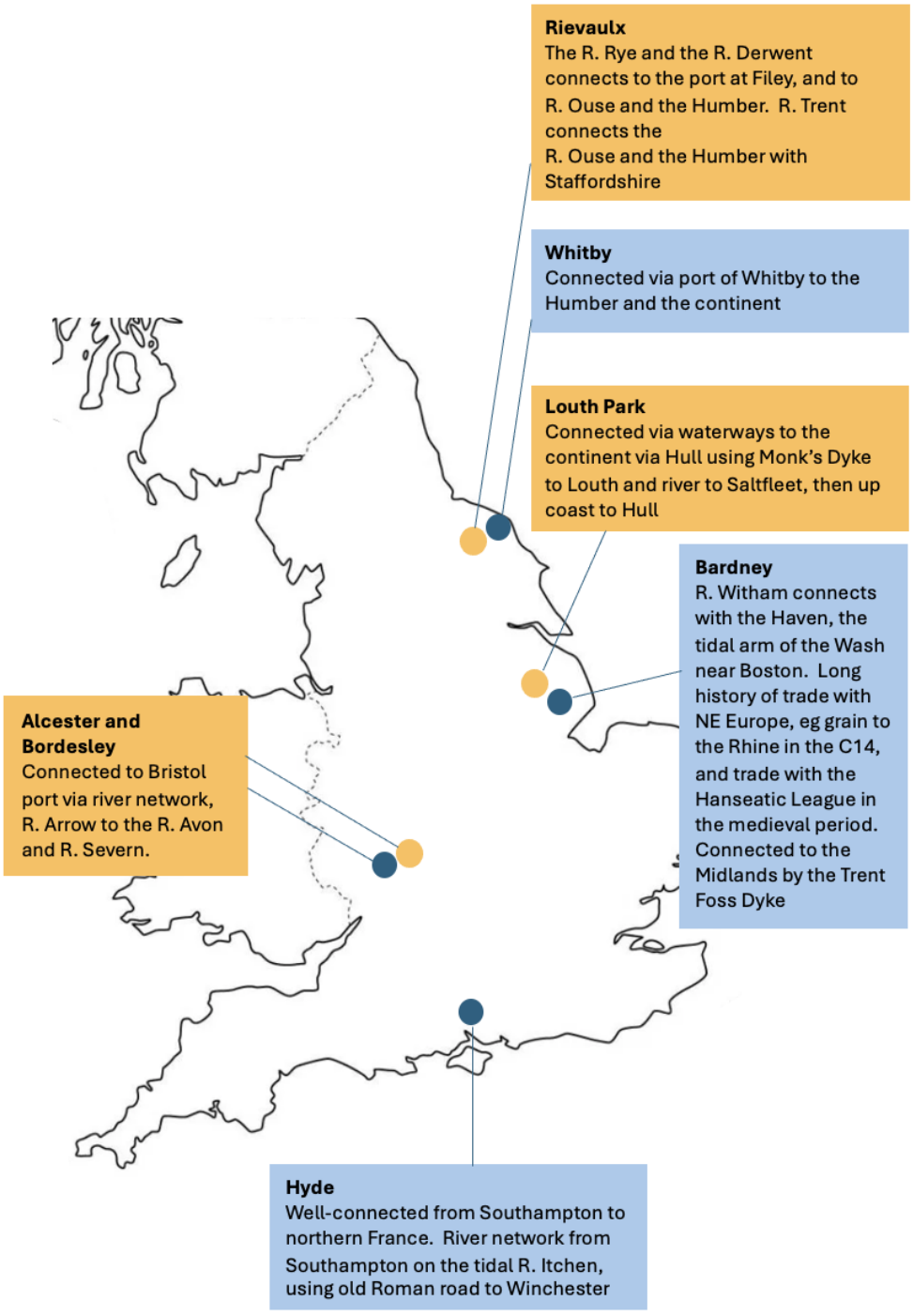


Figure 5.2 Some of the transport routes that may have been used for transporting window glass to the abbey sites from English and the continent glass production areas

5.4.2 Lincolnshire: Bardney and Louth Park

Bardney and Louth Park abbeys were situated in the Witham Valley in Lincolnshire. In the medieval period Lincolnshire was fertile and affluent and at the time of the Dissolution contained over 50 religious houses with nine in the Witham Valley. The area had a long history of trade with north-western Europe. Faith (2012, p. 676) discusses the 'Humber zone', an area that included Lincolnshire that engaged in trading with Germany, the Low countries and northern France. Trade went through Hull and other ports along the coastline such as Boston, and inland ports including York, where glass painting workshops were situated (Brown, 2019). A traversable system of roads and a network of waterways ran through Lincolnshire and connected the abbeys with South Yorkshire via the Don, and the Midlands via the Trent. Before the 17th century these two rivers were connected and water travel would have been possible to Burton-on-Trent. The Calendar of Charter Rolls for 1300-1326 records the permission given to the monks of Louth Park to use the river system to transport peat: '...carry it [the peat] and other goods to the waters of the Use [Ouse] and Don, and there load ships and take them thence freely and without disturbance', quoted in Edwards (1987, p. 165, 168).

Louth Park was also connected via trackways to the town of Louth. The River Lud, which ran through Louth was connected to the coastal ports and also fed into the River Humber. In the late 13th century Monk's Dyke was enlarged and connected the abbey directly with the town of Louth. The River Witham connected Bardney Abbey to the coastal port of Boston, and in the north-westerly direction, to Lincoln. Here, the artificial cut of the Foss Dyke connected the Witham to the River Trent, which in the mid-14th century was navigable at least as far upriver as Burton-on Trent (Edwards, 1987, p. 186), with access then to the Staffordshire glasshouses.

5.4.3 West Midlands: Alcester and Bordesley

The abbeys were close in proximity to each other on the south bank of the River Arrow. The river position provided a connection via the rivers Avon and Severn south-westerly to the Bristol Channel and north-easterly to Warwick and Coventry. Bristol was a well-established port in the medieval period with maritime connections to the continent including western France and Normandy (Miller, 1964, p. 27; Lipson, 1956, p. 186). Staffordshire was accessible by boat along the River Avon and its tributaries, and the glass may even have been painted 'en route' at Coventry. The area was wealthy through agriculture, in particular sheep farming, and Coventry to the northeast was an important town involved in the trade of wool. In the late 14th century and 15th century John Thornton, who was the master glazier for the Great East Window at York Minster, maintained a glass painting workshop in Coventry (Freestone et al., 2010, p. 22).

5.4.4 The south coastal area: Hyde, Hampshire

Hyde Abbey was located in the historic suburbs of Hyde in Winchester, a town with connections to the Christian church dating to the 7th century. There were 15 monastic houses

established in Hampshire, some like Hyde with roots to the pre-Norman period, for example the Benedictine houses of St Swithun and St Marys both in Winchester (Kennedy, 1970, p. 65).

Hyde Abbey was connected to Southampton around 26 miles away via the River Itchen, (Edwards, 1987, p. 305) probably also using the Roman road for part of the journey. Southampton was a major port in the medieval period, facilitating trade with Normandy, Brittany, the Low Countries and Germany (Platt, 1973, p. 31) and dressed stone from Caen in Normandy was supplied for the abbey through this port (hyde900.org.uk, 2020). Hyde Abbey was also connected to the Weald via established road routes. Winchester was a major junction in the medieval period on the road between Southampton and London with Guildford and Fareham also en-route, which were both only around 12 miles away from Chiddingfold in the Weald. Edwards, (1987, p. 109) describes medieval roads as well utilised by a variety of traffic at all times of the year and thus the journey to Winchester by road from the Wealden glasshouses may have been a fairly unassuming undertaking.

5.5 The abbeys, archaeology and assemblages

The following section describes each individual abbey in the study with reference to its construction, size of the community and its dissolution in the 16th century (shown on a timeline for each abbey using the key shown in figure 5.3). The archaeological fieldwork and retrieval of the window glass are described and the assemblages are detailed.

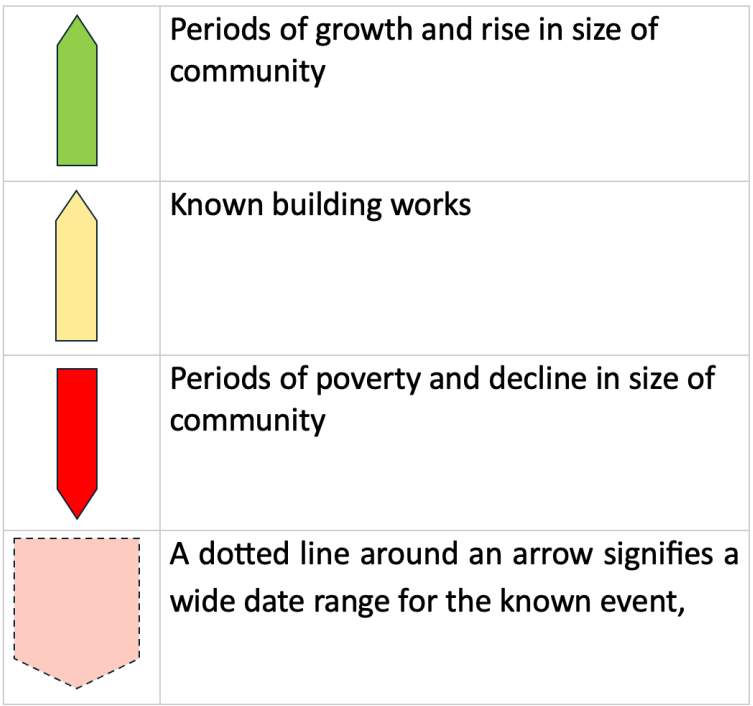
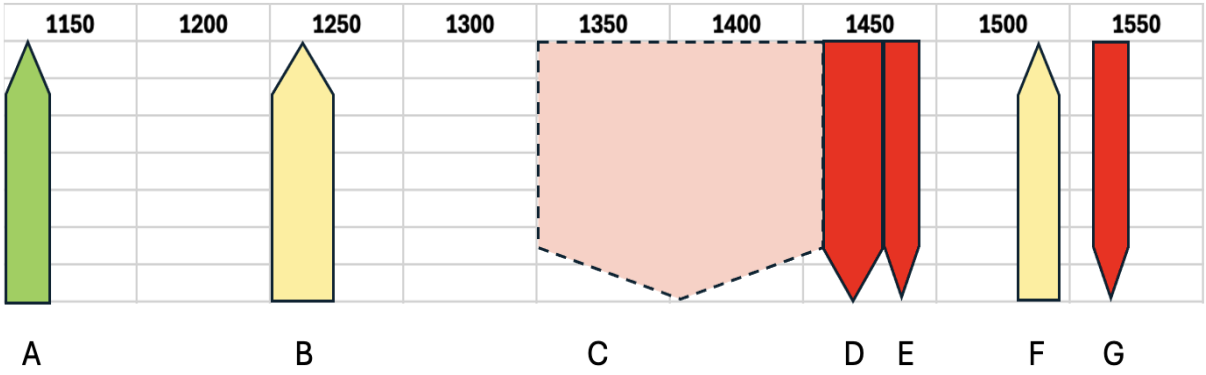


Figure 5.3 This key describes the coloured arrows used in each of the timelines showing the fluctuating fortunes of each abbey

5.5.1 Alcester Abbey, Warwickshire

Alcester Abbey was founded around 1138 on an island site between the River Arrow and a moat near to the town of Alcester in Warwickshire. Since there is no standing masonry and with the loss of site notes from the 1938 excavation, the configuration of the abbey has been reliant on the interpretation of the surviving low relief earthworks. This was undertaken in 1973 by Worcester County Museum and shows that the abbey had the general plan of a smaller Benedictine house with the church at the highest point of the site (Bond, 1973). The church and refectory were constructed in locally quarried stone around 1238. The historical records for Alcester Abbey are meagre; however, Styles (1941, p. 20-38) provides a comprehensive synthesis of the abbey's history through charters and letters, a summary of which is presented as a timeline (figure 5.4). It is unknown how many monks lived at the abbey for most of its history other than in 1444, when there were a few monks and an abbot, and accordingly, in 1466 it was absorbed by Evesham Abbey and downgraded to a priory. Archaeological evidence shows that the Chapter House was rebuilt around 1515 probably to accommodate a smaller community of the priory (Minutes, 1939, Birmingham Museum Archives). Alcester was dissolved in 1536. A summary of the known building work and community size, where known, is shown in figure 5.4.



A	1138	Abbey built
B	c. 1238	Church, refectory and Chapter House reconstructed
C	C14 pre 1336	Church fallen into ruin
D	1444	'few monks left'
E	1465	Absorbed by Evesham Abbey, downgraded to a priory, 1 abbot left
F	1515	Ruined church reconfigured
G	1536	Abbey dissolved

Figure 5.4 Timeline showing the fluctuating fortunes of Alcester Abbey, see figure 5.3 for key (Styles, 1941; Threlfall, 1939)

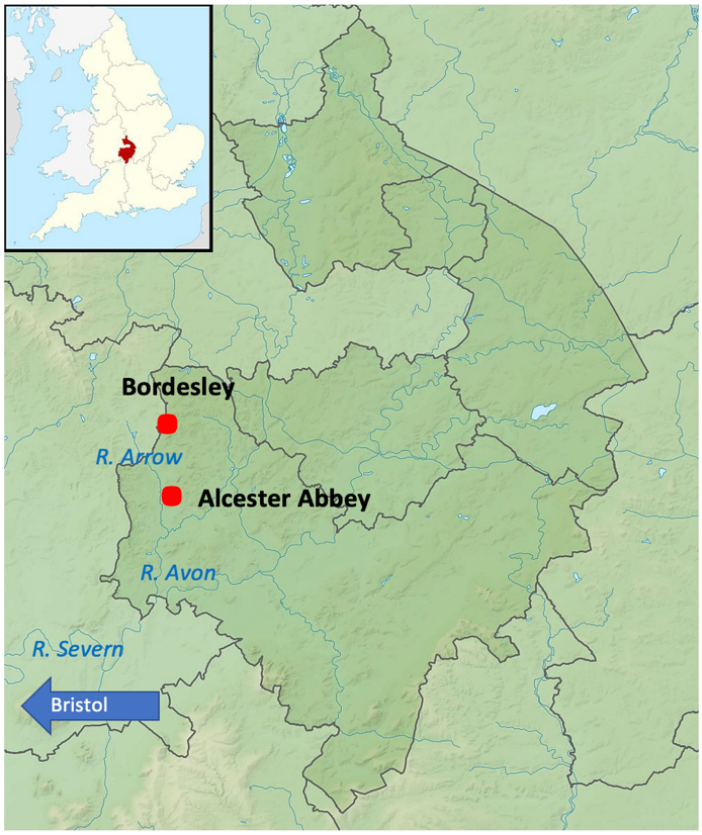


Figure 5.5 Location of Alcester Abbey. Also shown is neighbouring Bordesley Abbey (see 5.5.3) and river routes to the port of Bristol

Archaeology

The main excavation at Alcester was undertaken in 1938 by R I Threlfall, the Director of Archaeological Excavations for the Birmingham Archaeological Society. All notes and most of the finds were lost in World War Two, although minutes from the reading of a short paper written by Threlfall in 1939 has survived (Dungworth, 2015). This records the excavation of buildings that included the Chapter House where a large assemblage of medieval stained glass stripped of its lead was found. It is from this large assemblage that a selection has been made for use in this study. The minutes describe some of the glasses, noting fragments that came from 'an exquisite 14th century window of stained glass', describing the colours of some of the glasses and mentioning one fragment decorated with an amusing devil's head (Minutes, 1939, Birmingham Museum Archives). It was also noted that a hemispherical hole used for melting lead was located in the refectory floor. World War Two prevented further work by Threlfall, and it was only after his death that the assemblage of window glass was donated to Historic England.

The assemblage

The assemblage from the 1938 excavation consists of approximately 1200 fragments of decorated and undecorated window glass dated stylistically from the mid-13th to the early 15th

century. The whole assemblage was catalogued with advice from Rachel Tyson (glass scholar) and summarised as follows:

The majority of the glasses show some degree of degradation in the form of pitting on the external faces of the fragments, with brown to almost black corrosion on both sides. Some fragments are iridescent, and a number are devitrified. Around 15% of the assemblage is too degraded and opaque to discern the colour of the base glass. Approximately 25% of the assemblage is intentionally coloured, these are: red and flashed red, blue and flashed blue, dark green, amber, pink and purple, and around 12% of the assemblage comprises silver stained fragments. The remainder of the assemblage is pale green and colourless.

Around 60% of the assemblage retains at least one grozed edge, and square, round and rectangular quarry shapes were recovered. There are a number of broad-made glasses but only a few of the glasses show possible evidence of crown production.

Based on stylistic decoration and the technique employed in the application of the paint the assemblage can be divided into four stylistic periods: the earliest motifs are mid-13th century stiff leaf grisaille and Lombardic inscriptions and border patterns. The second group is naturalistic grisaille, which dates to the 13th / 14th century. The third group is early to mid-14th century and includes foliage, rinceau and figurative motifs, plus examples that are silver stained. One sample from the 15th to the 16th centuries is painted with lettering. Thirty-nine representative samples were selected for the study.

5.5.2 Bardney Abbey, Lincolnshire

Bardney Abbey was a Benedictine monastery founded in 1087 initially as a priory on or near to the site of a former 7th century abbey that had been destroyed by Vikings in the 9th century. The priory was raised to the status of an abbey in 1115 and is located on a former island site, one km north of Bardney village and 18 km east of Lincoln (Brakspear, 1922, p. 2) (figure 5.6). It was the first of a cluster of abbeys founded in the Witham Valley in the Lincolnshire Wolds (Cope-Faulkner, 2009).

Church building was begun shortly after the foundation of the monastery using limestone and sandstone from the nearby quarry at Spilsby (figure 5.6). The plan is typical of a Benedictine monastery albeit with an extended choir (Cope-Faulkner, 2009) (figure 5.8). It was built piecemeal over a long period of time (evidenced by the changing architectural styles), and after the east end was completed in the late 12th century the church became operational. Archaeological evidence shows that the construction was ambitious, with a full aisled choir and a high vault. Remnants of high-quality carved masonry demonstrate that the west front was ornamented with tiers of pointed arches, similar to Lincoln Cathedral (Brakspear, 1922, p. 33). It was completed in the mid-13th century (Brakspear, 1922, pp. 2–4).

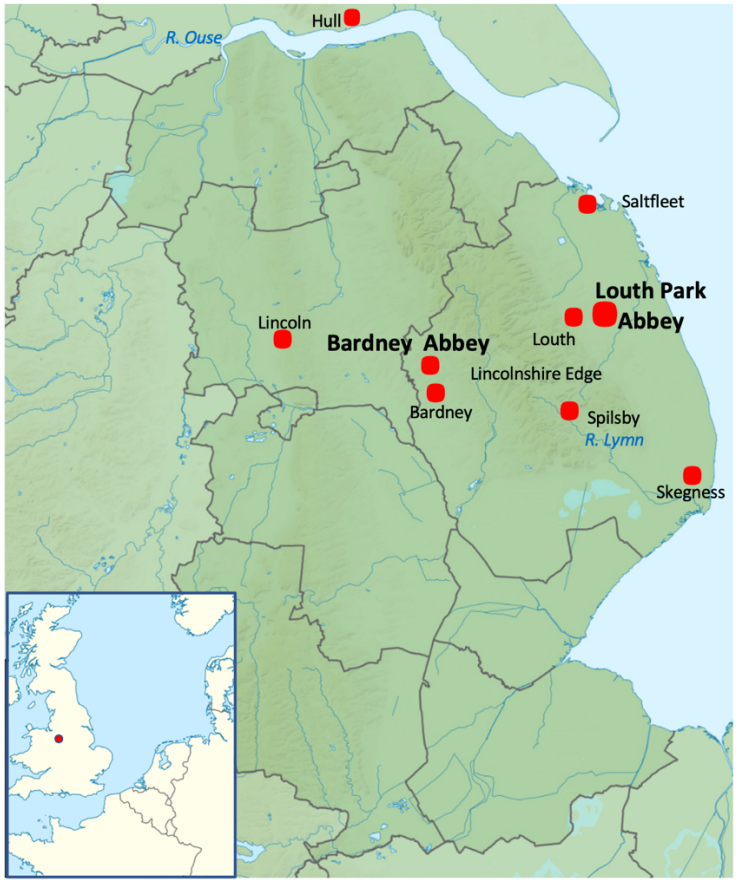
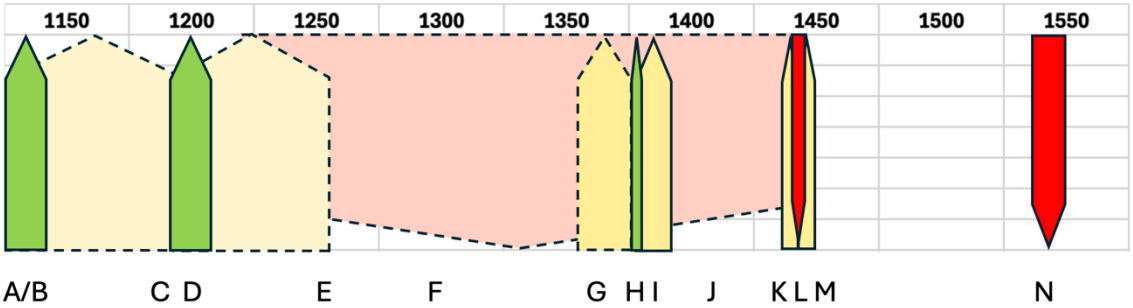


Figure 5.6 Location of Bardney Abbey. Also indicated is neighbouring Louth Park Abbey (see section 5.5.5 below), nearby ports and Spilsby, from where stone used to build parts of the abbey was quarried.

A summary of the abbey's history is presented as a timeline (5.7). Bardney Abbey was surrendered in 1538 and the west range remodelled to a private dwelling. The site is now earthworks although the outline of the abbey's buildings can still be seen (figures 5.10 and 5.11).



A	1087	Founded as priory, cell of French Benedictine abbey at Charroux
B	1115	Becomes independent, raised to abbey, endowments and grants from King Henry I
C	Late C12	Cloister, Chapter House, dorter, reredorter and frater constructed (Brakspear)
D	C12/C13	Unknown number of monks but greater than 20
E	Mid-C13	Church finished, Serious debts
F	End C13-1318	Lawsuits, poverty, abbot resigns
G	C14	New cloister arcade with early perpendicular tracery windows after 1350
H	1376	Community comprises prior and 20 monks
I	1379-83	New donor window in west wall of frater
J	1406	Henry IV visits, poverty continues, nave adapted for Lady Chapel
K	1437/8	New transomed windows inside walls of frater
L	1437/40	Buildings dilapidated, community of one abbot and 16 monks, debt
M	1444	Renovations to church
N	1538	Dissolved, Abbot, Prior and 12 monks, buildings remodelled for private house

Figure 5.7 Timeline showing the fluctuating fortunes of Bardney Abbey (Laing, 1914; Brakspear, 1922; Harrison; 2012). See figure 5.3 for key

Archaeology

Between 1909-1915 the church and a range of buildings around the cloister, including the refectory, were excavated by the local Vicar of Bardney, Canon Charles Laing. A hole in the nave showing signs of a fire was interpreted by Laing as a lead melting hearth (and which may have been part of the deconstruction of the windows at or soon after the Dissolution); the report on these excavations was published by Harold Brakspear after the death of Laing (1922) (see 5.9). Left exposed until 1933 the site was then backfilled, and in 2011 Archaeological Project Services (APS) with the Bardney Heritage Group and financed by the Heritage Lottery Fund dug test pits in the west end and south aisle of the church and excavated the 1930s backfill adjacent to the refectory, which was assumed to relate to the abbey. From the excavations of the refectory backfill, 312 fragments of glass weighing a total of 7.63 Kg were retrieved (Cope-Faulkner, 2011) (figure 5.9). The assemblage was deposited with Lincolnshire Archives and two samples were donated to the Bardney Heritage Centre.

The assemblage

As noted in the APS excavation report, the majority of the assemblage is decayed, dark, opaque with a granular texture (Cope-Faulkner, 2011). The poor condition limited the study to 23 samples. This sample set consists of 19 decorated and 4 undecorated fragments dated from the 12th/13th century to the 15th century. A number of the fragments have retained original, grozed edges but only three samples have a discernible shape either rectangular or triangular. One sample has an original cut edge. There are two samples with evidence of broad-sheet production and one 12th/13th century murrey coloured sample that tapers in thickness from 2.5 mm to 1.5 mm suggesting crown production. Five other intentionally coloured glasses in the sample set are striated and flashed red, green and blue. The remaining 16 are naturally colourless or pale green.

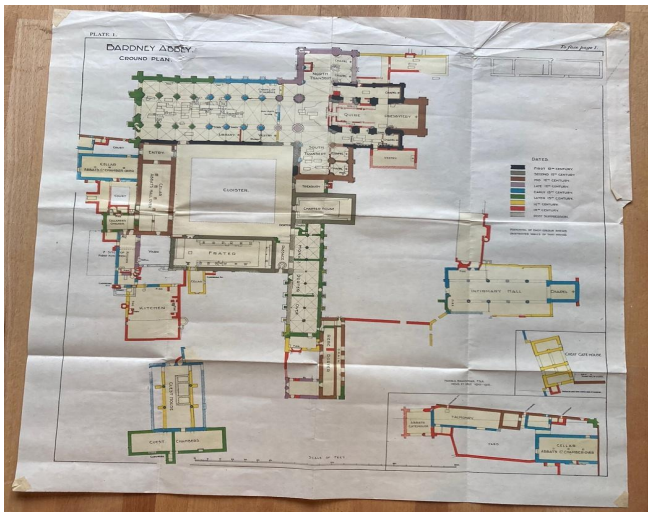


Figure 5.8 Photograph of a map of Bardney Abbey (courtesy of Bardney Heritage Centre)

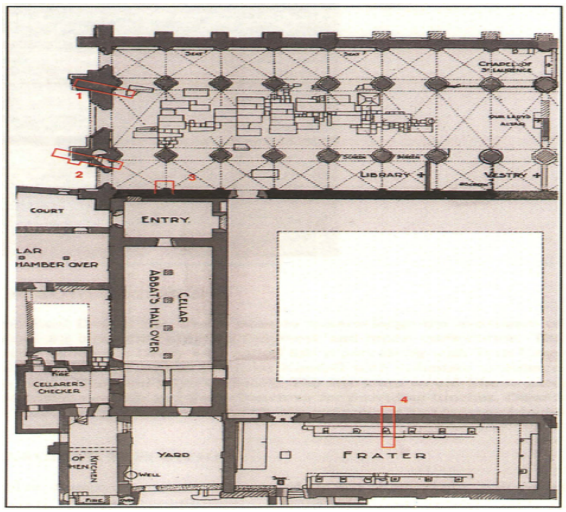


Figure 5.9 Bardney Abbey Site plan taken from Brakspear, 1922 marking location of window glass deposit from the refectory (frater) (marked number 4 in red)

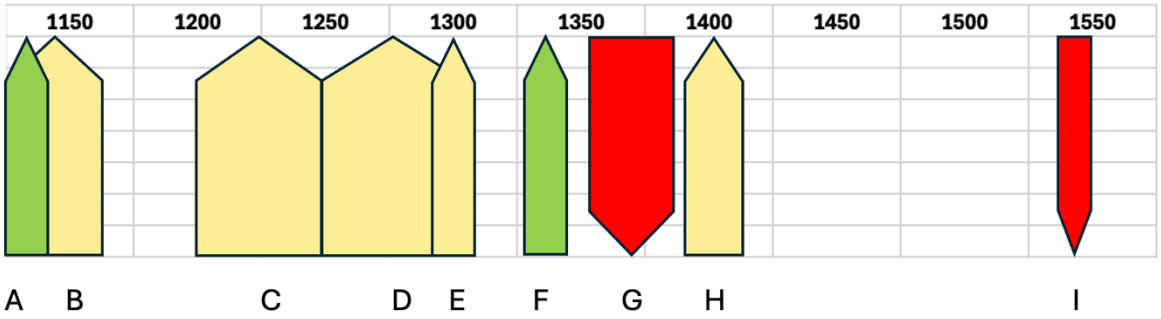
Figure 5.10 Photograph taken from noticeboard (Jews Court Trust) at the abbey site showing the earthworks in relief (north is at the bottom of the picture). Approximate location of window glass find-spot is circled in red. Photograph by B Stone, author (2023)

Figure 5.11 Photograph showing the bases of the columns of the nave as earthworks, looking eastwards. Photograph by B Stone, author (2023)

5.5.3 Bordesley Abbey, Worcestershire

Bordesley Abbey was a Cistercian abbey founded between 1138 and 1140 on marshy ground on the south bank of the River Arrow, now near Redditch. The abbey was built of green and then red sandstone; the latter was probably locally quarried. Rebuilding, at times major, occurred throughout much of the abbey's existence, some of which was caused by structural instability. Parts of the church were rebuilt around 1200, in the second half of the 13th century and around 1400. At the end of the 13th century the gate chapel was rebuilt as a lavishly decorated structure (Hirst, Walsh and Wright, 1983, p. 43, 54; Astill, Hirst and Wright, 2004, p. 113).

A summary of the building history and size of the community is presented in the timeline (fig 5.12). Bordesley was dissolved in 1538, and the abbey was systematically dismantled with the building materials either robbed or sold (Hirst, Walsh and Wright, 1983). Documentary records from 1538 show the sale of windows from the north and east sides of the cloister (Rahtz and Hirst, 1976, p. 22). The gate chapel was the sole building to survive post-dissolution, then acting as the parish church for Redditch until it was demolished in 1805, leaving the whole site as earthworks. A summary of the building-history of the abbey and numbers of the community, where known, are presented in figure 5.12.



A	1138	Monastery founded, around 100 monks
B	1150-60	Church completed
C	1200-50	Parts of east end and choir rebuilt; new stone night stair
D	2nd half C13	Church crossing rebuilt, tower raised, followed by collapse of crossing pier early C14
E	Late C13	Gateway chapel rebuilt
F	1332	Community of 60 monks, lay and hired
G	1380	Community of 14 monks plus lay
H	c. 1400	Nave and cloister rebuilt; contraction of claustral range
I	1538	Abbey dissolved, abbot and 19 monks

Figure 5.12 Timeline showing the fluctuating fortunes of Bordesley Abbey, see figure 5.3 for key (Woodward, 1866; Rahtz and Hirst, 1976; Hirst, Walsh and Wright, 1983; Astill, Hirst and Wright, 2004)

Archaeology

The site was first investigated by J M Woodward in 1864 (Woodward, 1866), who proposed a ground plan of the main claustral buildings from keyhole excavations; finds included window glass fragments from areas of the church. He reported that the condition of the glass found at the west end of the nave was much better than glass from elsewhere and suggested that these glasses made up the Great West Window (Woodward, 1866, p. 103). The nave glasses were illustrated (fig 5.13), and some of these glasses depicted may form part of the study material presented here.

The Bordesley Abbey Project, begun in 1969, was a collaboration between the Redditch District Council and the universities of Birmingham, Reading, Rochester USA and York. The project undertook a programme of excavations, focussing on the church and the industrial site. A Manpower Services Commission (MSC) training scheme excavated the gatehouse chapel on the western boundary of the precinct. Window glass was retrieved from the abbey church and gate chapel and a Dissolution-period lead-melting hearth was found in the south transept (Rahtz and Hirst, 1976, p. 58, 74). The assemblage, amounting to 1400 fragments is currently in storage, care of Forge Mill Museum, Redditch, and the Bordesley Abbey Project.

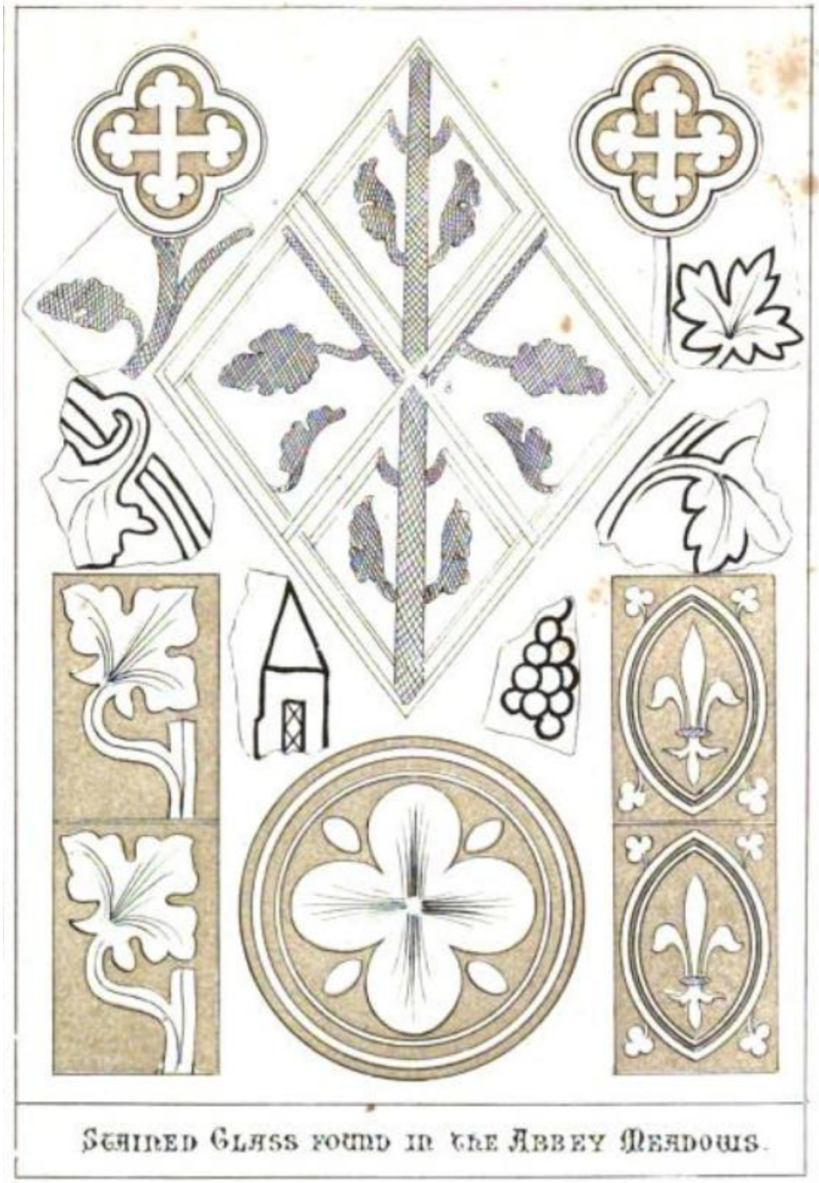


Figure 5.13 Illustration from JM Woodward investigations in 1864 (Woodward, 1866). Of interest is the unusual cross-hatched stems of the foliate design in the centre, a patterning that is visible on two fragments in the study (B1, B11, see section 7.4.1)

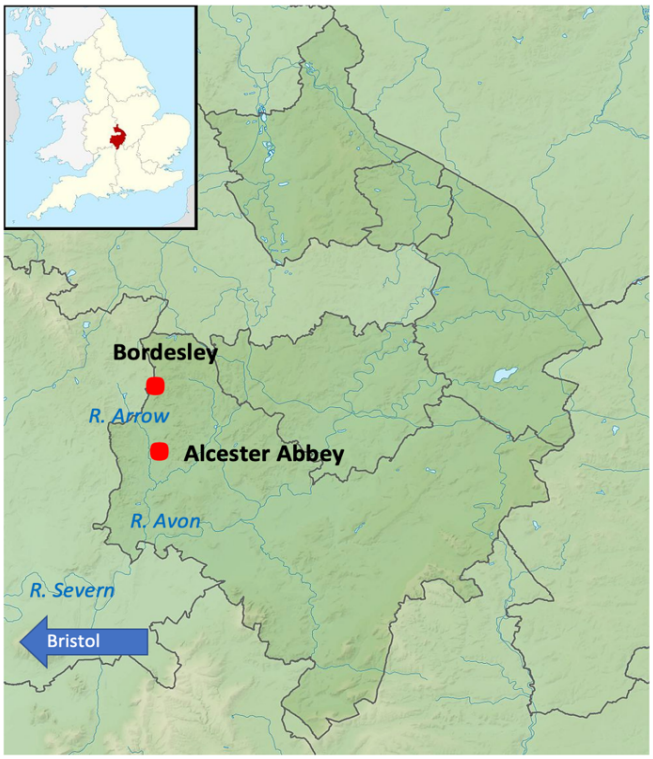


Figure 5.14 Location of Bordesley Abbey. Also shown is neighbouring Alcester Abbey (see 5.5.1) and river routes to the port of Bristol

Figure 5.15 Photograph of standing remains at Bordesley Abbey looking eastwards. Photo B. Stone, author (2025)

The assemblage

The selection of 40 samples that date from the 13th to the 15th century was dictated to a large extent by the condition of the glasses; many of the fragments are heavily corroded with a thick black-brown weathered crust, and others are friable and vitrified. Four of the fragments had been consolidated with PVA before the study. Fourteen fragments retain at least two original edges and of these eleven have discernible shapes. There is also a single bull's eye cut from the centre of the crown that shows no signs of having been installed in a window.

Thirty-five of the sample set are decorated, five are undecorated and the selection includes nine coloured glasses, green, blue, amber and red, one fragment that is silver-stained plus examples of broad and crown production. The earliest motifs are from the stiff leaf grisaille repertoire and dated to the early to mid-13th century. A second group contains glasses decorated with 13th/14th century naturalistic grisaille, and a third group is dated to the 14th century and is decorated with heraldic devices, diaper patterns, black gothic lettering, micro-architecture and foliate designs that are infilled with unusual cross-hatching. The fourth group comprises glasses dated to the 15th century with motifs including stipple shaded micro architecture, background and border decoration, and a part angel wing from a possible figurative window. All of the glasses in the sample set have been illustrated by Ellen Walsh and Lesley Collett for the Bordesley Abbey Project but have been re-drawn for this study for consistency.

The find-spots

All of the glasses from Bordesley have finds-pots, which are listed in the table 5.4 and shown on the plan (fig 5.16). The excavation concentrated around the church in the north of the site and all 31 glasses from this area are assumed to be originally from the church including the eastern end, south transept and south aisle, and the gatehouse chapel in the west of the precinct where nine of the study's glasses were retrieved (Hirst and Walsh, 2025, conversation with author, 8 May 2025).

Table 5.4 Find-spots of the window glass in the study from Bordesley Abbey

Find spot	No. fragments in the study
Northeast cloister walkway	11
Outside the east end of the church	10
Southeast exterior	1
West end of church	5
Church choir	2
Church south transept side chapel	1
Church crossing	1
Gate chapel	9

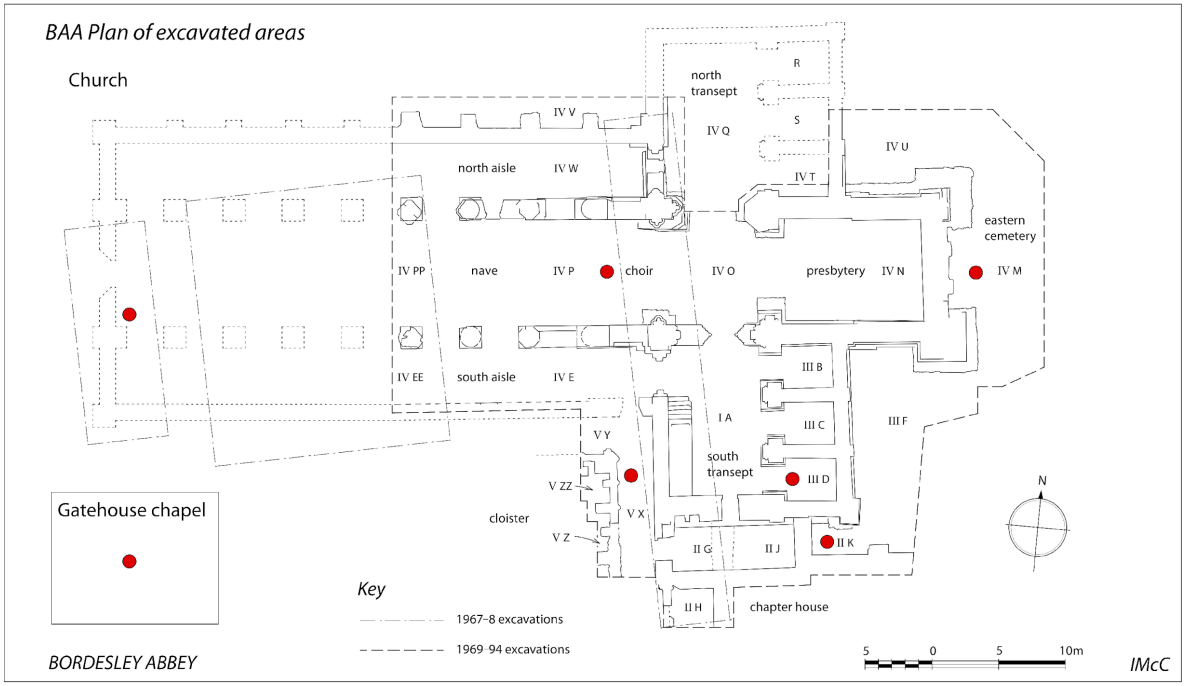
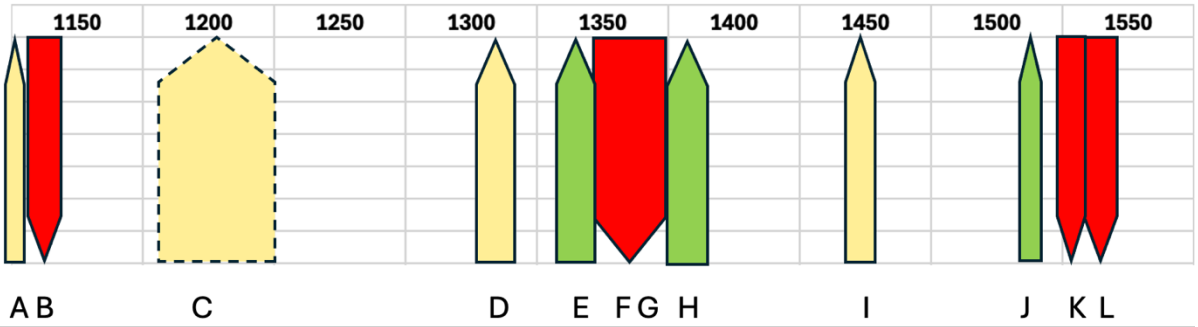


Figure 5.16 Plan of Bordesley Abbey, drawn by Ian McCaig, who is part of the Bordesley Abbey Project Team

5.5.4 Hyde Abbey

Hyde abbey in Hampshire was a Benedictine monastery originally built in 1110 to rehouse the community of monks from the New Minster in Winchester and contained treasures and relics including the bones of King Alfred the Great (Doubleday and Page, 1903). In 1141 the abbey was destroyed in the Anarchy and the rout of Winchester but partially re-built around 1182. Stone was quarried locally and from Caen in Northern France (Hyde900.org.uk, 2020.) (figure 5.18). By 1312 the abbey was still partly in ruins due to lack of funds for maintenance (the cloisters, for example) and a campaign of collections was necessary (Bramston and Leroy, 1884). The size of the community at this time is unknown but just prior to the Black Death in the mid-14th century the number of monks at Hyde was 30-40, a number that halved to 20 following the Black Death (Gasquet, 1893, p. 377). Periods of poverty and debt were allied with the deterioration of many of the abbey's buildings and the size of the community rose very little; when the abbey was dissolved in 1538 there were just 21 monks present. By 1542 many of the buildings had been dismantled and the material sold (Bramston and Leroy, 1884). In the 19th century terraced housing was built over the site, including King Alfred Terrace. A summary of the fluctuating fortunes of the abbey and the building episodes and size of the community are presented in a timeline (fig 5.17).



A	1110	Abbey built, funded by Henry I
B	1141	Abbey destroyed during The Anarchy and the Rout of Winchester
C	1182	Abbey partially rebuilt
D	1312	Part of monastery in ruins, campaign of church collections for repairs
E	1340s	Community of 30-40
F	1349-50	Community devastated by Black Death, community around 20
G	1352	Impoverishment
H	1377	Financial recovery
I	1446	Bell tower and other parts of complex rebuilt donation by Bishop of Winchester
J	c. 1516	Visit of Henry VIII
K	1530s	Community numbers 26
L	1538	Hyde Abbey dissolved, community numbers 21 plus abbot

Figure 5.17 Timeline showing the fluctuating fortunes of Hyde Abbey. See figure 5.3 for key (Bramston and Leroy, 1884; Gasquet, 1893; https://www.hyde900.org.uk)

Archaeology

From 1972 to the current day a series of excavations by Winchester Museum Service, Wessex Archaeology and the Hyde900 community archaeology group established the location of many of the precinct's buildings. In 2020 a Hyde900 community excavation took place in the gardens along King Alfred Terrace, an area originally within the abbey's inner precinct. In the garden of number three King Alfred Terrace, a deposit of window glass was retrieved. This deposit is thought to be concurrent with the wholesale post-dissolution deconstruction of the monastic buildings (Hyde900.org.uk, 2020). The whole assemblage was loaned to Historic England. A catalogue of the full assemblage was undertaken as part of the project and a sub-set selected for analysis.

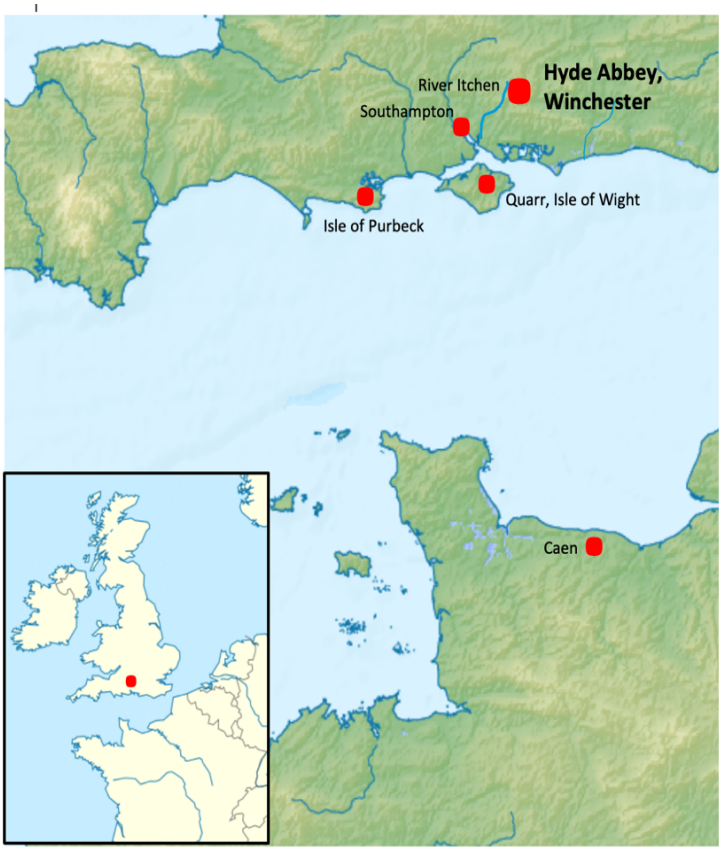


Figure 5.18 Location of Hyde Abbey near to the south coast. Map indicates the River Itchen, port of Southampton, and Quarr on the Isle of wight, Caen and the Isle of Purbeck, from where stone used in construction was quarried

The assemblage

The whole assemblage was catalogued. It comprises 923 fragments of decorated and undecorated glass dating stylistically from the mid-13th century to the 15th century. Around 80% of the assemblage is uncoloured, either naturally tinted pale green or colourless. The remaining 20% is deliberately coloured, with approximately the same amount of blue and red fragments. Approximately 35% of the red glasses are flashed and around 3% of the assemblage is silver stained. Approximately 80% of the total number of glasses are undecorated and 20% decorated. The 13th century glasses are decorated with motifs from the stiff leaf grisaille repertoire, the 14th century are decorated with naturalistic motifs and inscriptions, and a third group is dated to the 15th century and demonstrates more sophisticated painted techniques such as stipple shading, as well as silver stain, and represents figurative and micro-architectural designs. A small number of fragments have a discernible original shape, which include rectangular, sub-rectangular and curved. For the most part the assemblage is broad glass although there is one bull's eye, an off-cut from crown production, which shows no evidence of having been part of a window installation (see section 2.6.2). Forty-nine representative samples were selected for analysis.

5.5.5 Louth Park Abbey, Lincolnshire

Louth Park Abbey was a Cistercian monastery founded in 1139 as a daughter house of Fountains Abbey (Platt, 1984, p. 46). The location was remote from the town of Louth in Lincolnshire, on a terrace above the River Lud. The first stone-build structures were constructed in the 12th century; there was no local building stone and limestone was brought from Tadcaster and also most likely from Spilsby (see figure 5.6) and Lincoln Edge, while local chalk was used as infill in the walls. The church was built piecemeal, as evidenced by progressively improved stonework westwards down the nave and at pace with the flow of income. Archaeological evidence shows that the initial phase of construction was of the chancel, crossing, and two or three bays of the nave (Locking, 2022, p. 7, 9).

In the early 13th century Louth Park was impoverished, however in 1227 Richard of Dunholme (also spelt Dunham), a former monk at Kirkstead Abbey became abbot and revived its prosperity. During the second and third quarters of the 13th century it received increased revenues and endowments, for example, in 1239 the Dean of Lincoln financed a substantial campaign of building. According to the Louth Park Chronicle, which was a Latin chronicle written in 1413 that includes a history of the abbey from foundation in the 12th century until the 15th century, Dunholme completed the construction of the cloister, dormitory, Chapter House, gatehouse, and the west end of the church. During Dunholm's time as abbot the community of monks increased to 60 and the lay brothers to over 150. The Louth Park Chronicle also details substantial repairs to buildings in the complex around 1520 to 1530 (Coppack and Harrison, in preparation, p. 9–12, 14).

Ten monks remained at Louth Park abbey when it was dissolved in 1536, after which time the buildings were dismantled and materials were sold (Locking, 2022, p. 87). That the bells and lead alone were valued at nearly twice that of the abbey's holdings, and twice as high as any other dissolved houses demonstrates the wealth and success that the abbey had experienced. A study of the displaced architectural fragments from the church enabled the elevations to be understood and a direct comparison made with the churches at Kirkstall and Fountains abbeys (Coppack and Harrison, in preparation, p. 43, 47). A summary of the fluctuating fortunes of the abbey and building phases is presented in the timeline (fig 5.19).

A	1139	Abbey founded
B	C12	Piecemeal construction of church
C	C12/13	Financial demands from the Crown, period of penury
D	1227	Abbot Dunholme's campaign of construction begins
E	1239	Large donation from Dean of Lincoln to fund building, 1260 chapels built
F	C13 first half	community of monks increased to 60 and lay brothers to over 150
G	C13/14	Wool market crashes and failing crops forces abbey into debt
H	1315	Church completed
I	1334	Abbey taken into King's Protection
J	c. 1530	Substantial repairs to abbey's buildings
K	1536	Abbey dissolved

Figure 5.19 Timeline showing the fluctuating fortunes of Louth Park Abbey, see figure 5.3 for key (Platt, 1984; Locking, 2022; Coppack and Harrison, in preparation)

Archaeology

From 1852 to the late 19th century most of the monastic buildings were excavated. Initially, this was inadvertently through the digging of stone for re-use but thereafter was an attempt to define the layout of the site and plan of the church. In 1857 during excavations in the west end of the presbytery, a find of painted window glass was reported in the Stamford Mercury (Coppack and Harrison, in publication). There is, however, no direct link between the window glass in this report and the assemblage of glass studied here.

The assemblage

In 2017 an assemblage of window glass was donated by Louth Museum to the Lincoln Cathedral conservation workshop for safekeeping. It was acquired for the study from this location. The whole assemblage of 967 fragments of glass was catalogued as part of the project as no other record exists. The glasses date from the 13th century to the 15th century.

Approximately 10% of the assemblage is decorated with painted motifs and the remaining 90% undecorated. Based on the stylistic decoration and the techniques employed in the application of the paint, the sample set can be divided into two groups. The first group is dated early to mid-13th century and comprises stiff leaf grisaille motifs. The second group comprises the 15th century black gothic lettering, a flower border, stipple shaded micro architectural detail and a partial monk's tonsure, some of which are silver stained.

Less than 5% of the assemblage is deliberately coloured, and there are just three colours present, blue, red and amber. The majority of the remaining glasses are naturally colourless or pale green. Most of the glasses show some degree of corrosion although only 10 fragments are completely opaque. Some of the glasses also show weathering in the form of pitting on the exterior side, although these are few. Many of the fragments retain original grozed edges and discernible shapes are square, curved, rectangular, triangular and one diamond shaped quarry. There are a large number of original, long, thin rectangular and curved border pieces

that are undecorated. Many fragments in the assemblage show evidence of broad production, and a small number of fragments have an undulating surface or significant tapering to suggest crown production. A representative sample set of glasses was selected for the study that comprises decorated and plain glasses, all of the coloured fragments, which numbers four, and glasses that demonstrate broad and crown production.

5.5.6 Rievaulx Abbey

Founded in 1132 near Helmsley in North Yorkshire as a daughter house of Clairvaux Abbey, Rievaulx Abbey was the first and most spiritually renowned Cistercian abbey in the North of England (Fergusson, 1988, p. 160) (figure 5.20). The secluded location in the Rye Vale was chosen to ensure an austere, observant and self-sufficient way of life. Most of the manual work at the abbey, including farming and ironmaking, was undertaken by lay brothers, the number of which peaked in 1167 when there were 500 lay brothers and 140 monks (Daniel and Powicke, 1950, 38).

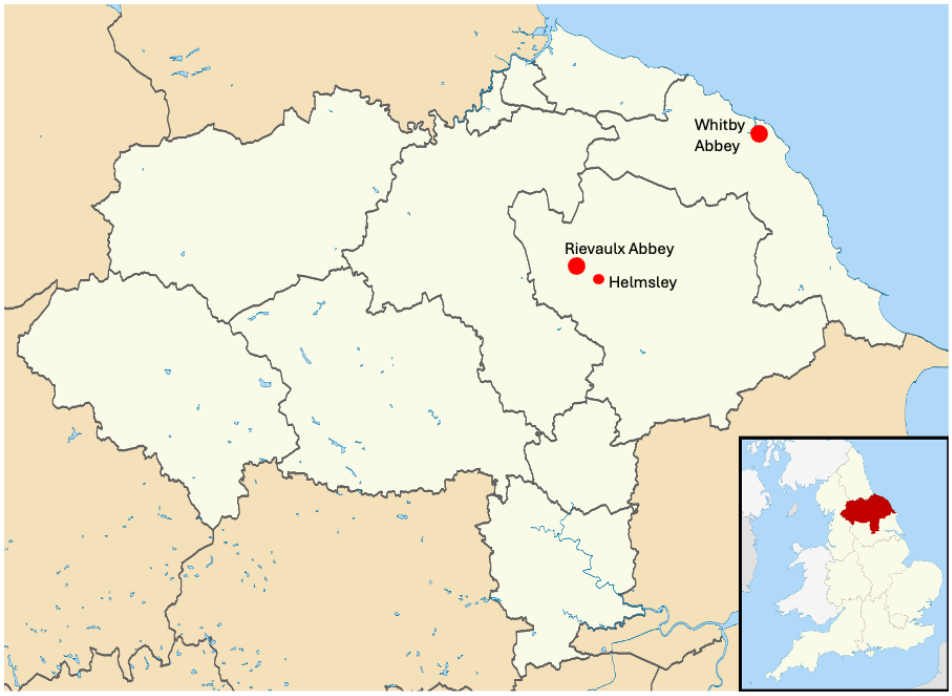
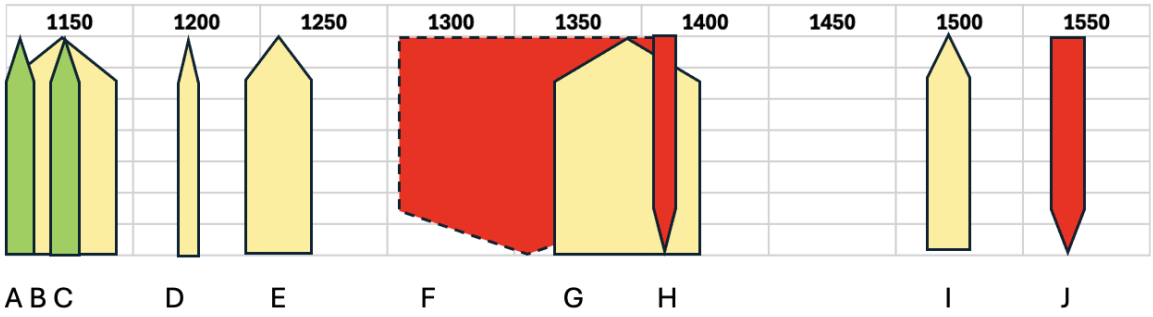


Figure 5.20 Location of Rievaulx Abbey in North Yorkshire. Also indicated is nearby Whitby Abbey

The church and many of the principal buildings were constructed soon after 1147 predominantly using locally quarried stone supplemented with some imported finer quality ornamental stone. There is evidence of subsequent building and remodelling of the abbey to accommodate the fluctuating size of the community, for example, the church was extended in 1220-39 and around 1340 it was reduced in size (Fergusson, Harrison and Coppack, 1999).

The church was built to a common plan in terms of the arrangement of specific buildings, yet on a south-east-northwest alignment, adapting to topography of the valley location, as opposed to the more usual east-west alignment, for example at Hyde. The architecture was a combination of influences from the French Cistercian houses at Fontenay and Clairvaux in the Burgundy/Champagne region, and local northern details derived from the traditions of the stonemasons. Evidence that building stones were numbered at the local quarry was probably done to speed up the building process (Fergusson, Harrison and Coppack 1999, p. 76, 81).

In the 14th century the Black Death devastated the community resulting in the loss of the lay brother labour force (Fergusson, Harrison and Coppack, 1999, p. 101), and in the late 15th century some of the key buildings in the nucleus of the complex were renovated, including the church and cloisters where new glazing was installed. A summary of the fluctuating fortunes at Rievaulx that includes building work and glazing episodes are presented in the timeline (figure 5.21).



A	1132	Abbey founded
B	c. 1130-60	Church, west and east ranges built
C	1147	Community of 150 monks and 150 lay brothers
D	Late C12	Refectory built
E	1220-39	Church extended and remodelled
F	1279	Abbey in debt, 1288 taken into royal protection
G	1340-1400	Church and Chapter House remodelled, new clerestory, east and west windows
H	1381	15 monks, 3lay brethren
I	1490s-c. 1500	Infirmary remodelled as abbot's lodging, church remodelled, windows enlarged, new glazed cloisters
J	1538	Abbey dissolved

Figure 5.21 Timeline showing the fluctuating fortunes of Rievaulx Abbey, see figure 5.3 for key (Daniel and Powicke, 1950; Fergusson et al., 1999)

The abbey was dissolved in 1538. Post-dissolution, many buildings in the outer precinct were systematically dismantled and the materials sold. The roofs of the claustral buildings were stripped and the lead recycled but the building stone was largely un-salvaged as it was low grade (Coppack, 2000, p. 129). An inventory compiled in 1539 details how the dispersal of materials was to be managed, including the window glass, which was sorted into three grades; put simply, the first – the best was retained for the Crown (including the west window that

was removed to Helmsley Castle), the second was sold and the third grade was stripped of its lead and dumped (Willmott, 2001, p. 46). While the ironworks continued to operate and even expand until eventual closure in the mid-17th century, the rest of the site remained undeveloped and the standing remains fell into ruin. In 1917 some of the structures were so unstable and dangerous that the Office of Works, the predecessor of English Heritage (EH), took guardianship of the site (Thurley, 2013, p. 100).

Archaeology

Archaeological investigations were undertaken by the Government's Work's Department between 1919 and 1928 under the supervision of Sir Charles Peers. The site plan was revealed, buildings consolidated, and the site cleared of debris and material culture including window glass, which was deposited with the now English Heritage (Thurley, 2013, p. 140). Most of the contextual information concerning the window glass is lost although some of the window glass was illustrated and their find spots recorded, see figure 5.22 and 5.24 below.

The assemblage retrieved from the investigations and site clearance comprises over 4,000 fragments dating from the 13th century to the 15th century. This glass, the third grade, was dumped when the lead came was stripped for recycling but also included are glasses that had remained in-situ and buried as the building collapsed post-dissolution. These are thought to include older glasses decorated with stiff leaf grisaille that was used as a 'sacrificial' border around newer insertions (of the first or second grade) (Mason, n.d.).

The assemblage

A sub-set of 29 decorated glasses was selected from the assemblage held by English Heritage at the Helmsley store in North Yorkshire, and comprises glasses decorated with 13th century stiff leaf grisaille motifs, 13th/14th century naturalistic grisaille, and 14th and 15th century figurative, architectural, background and border fragments. Also selected were coloured glasses: murrey, amber, blue, green and red, and examples of plain and silver-stained glasses. Samples of different shapes, and glasses showing evidence of both broad and crown production were also chosen. The find-spots of 14 glasses from the early 20th century excavation are known through the few site notes and illustrations that have survived. The locations are the Chapter House, north transept, the west range and the lay brother's door to the cloister. The approximate locations are marked on the 1937 plan below (figure 5.22). The remaining 44 findspots are unknown.

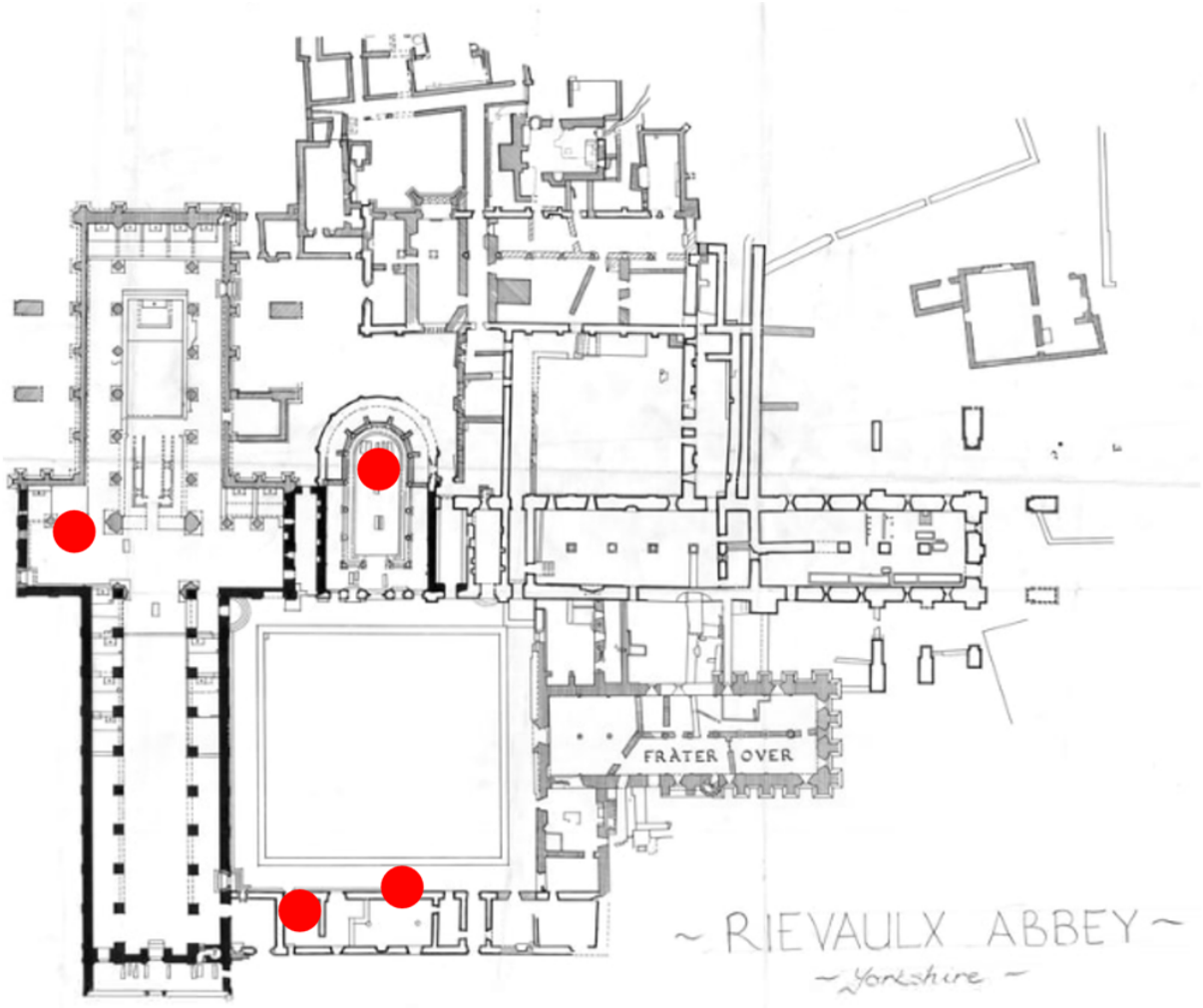


Figure 5.22 Plan showing find spots from the early C20 excavations of some of the glasses under study. The church is orientated north-south PF/RIE Historic England, 1937

The fragments with findspots are listed in table 5.5. Five of the fragments from the study were illustrated at the time of the excavation in the early-20th century (R2, R6, R4, R9, R63) and are shown in figure 5.24. A photograph of the surviving remains of the church is shown in figure 5.23.

Table 5.5 The find spots recorded at Rievaulx Abbey and number of fragments used in the study from these locations

Find spot	No. fragments in the study
Church, north transept	1
Church, lay brothers door to cloister	2
Chapter House	3
West range	8

Figure 5.23 Photograph of extant section of Rievaulx Abbey church from the north. Photograph B Stone, author (2023)

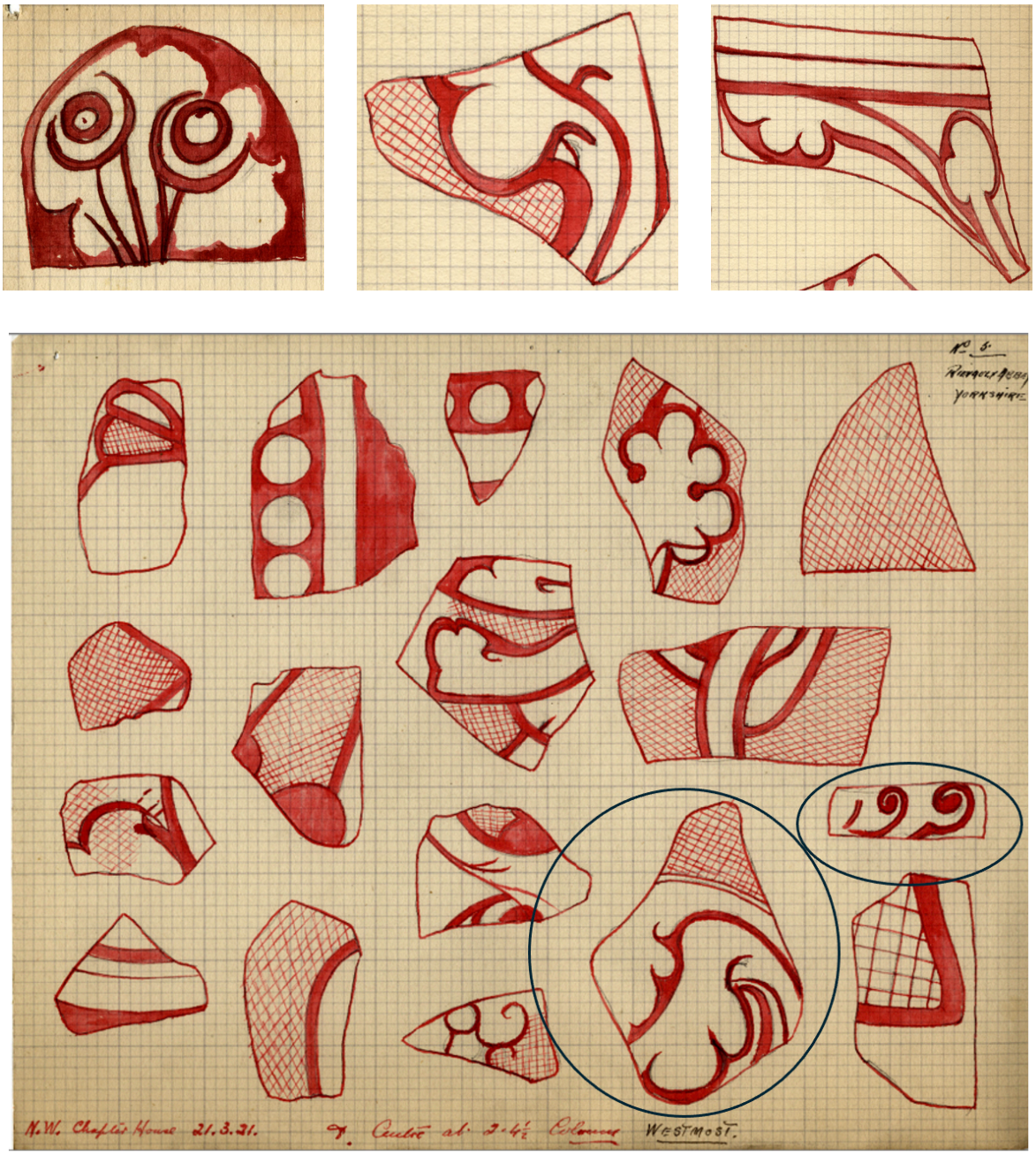


Figure 5.24 Five of the fragments from the study that were illustrated at the time of the excavation in the early 20th century. Top left, R2, top middle, R9, top right, R4, circled on left R6 and circled on right, R63

The sample set comprises decorated and undecorated glasses dated to the 13th to the 15th century. Twenty-two samples retain original grozed edges and the discernible quarry shapes are square, triangular, irregular and curved (R2 above). The majority of the glasses are colourless and tinted pale green, and where intentionally coloured are amber, dark green, flashed red and blue. Based on stylistic decoration and the technique employed in the application of the paint, the glasses under study can be divided into three dated groups: glasses that date to the 13th century and are decorated with motifs in the stiff leaf grisaille range of curling trefoils and cross hatched background (all of these glasses are naturally coloured pale green); glasses dated to the 14th century and decorated with foliage, lettering,

micro-architecture and figurative elements (eight of these glasses are coloured, green, flashed red, amber and blue); and glasses dated to the 15th century with decoration including figural and micro-architecture, and background motifs (four fragments are silver-stained, and one fragment is flashed red).

5.5.7 Whitby Abbey, North Yorkshire

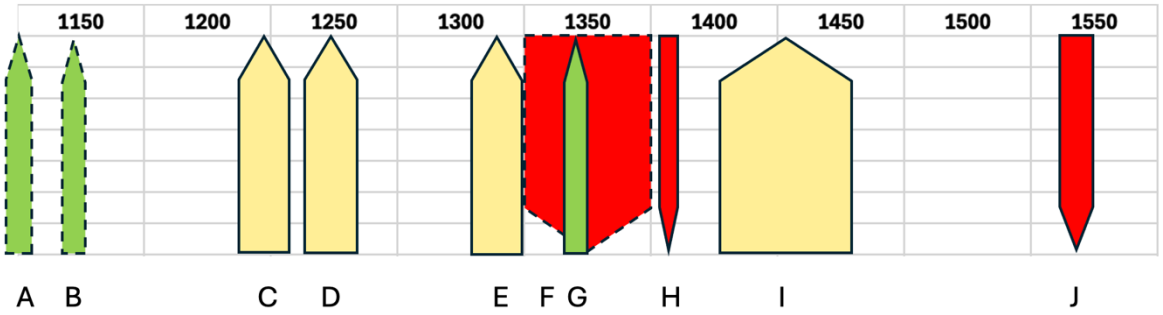
Whitby Abbey was a Benedictine monastery built of locally quarried sandstone on the site of a former Anglo-Saxon monastery in Whitby, North Yorkshire (see figure 5.20). The Benedictine order was granted the site in 1078 and a church is thought to have been built at this time. The monks abandoned the site in the late 11th century (Cook, 1960, p. 47). The construction of a new church began in the early 13th century, but it was not until the 15th century that it was completed (Clark, 1997, p. 4).

There were three main phases of construction, each phase was built in the contemporary architectural style (Atkinson, 1894) (figure 5.26).

- phase 1, c. 1220-35, choir and its aisles, two legs of tower, part of east wall and transepts, Early English, compared with choir at Rievaulx Abbey (Atkinson, 1894 p. 129)
- phase 2, 1245-60, transepts, west legs of tower, part of the nave, later Early English (Atkinson, 1894 p. 129)
- phase 3, c. 1310-25, west end of the nave, west front and east end of the crossing tower, Decorated style (Atkinson, 1894 p. 131)

While inheriting the defensive hill-top location, the abbey was also very exposed and suffered storm damage that necessitated frequent repairs to the fabric of the building and to the windows. The later Perpendicular style opening in the west end of the nave, contained a window which is dated to the 15th century (Atkinson, 1894, p. 135; Clark, 1997, p. 4). Two of the glass samples also show evidence of repair (W18, W20), perhaps as a result of storm damage. Some of the events and building work at the abbey are summarised in the timeline figure 5.25.

When Whitby Abbey was dissolved in 1539 the community numbered 20 monks. The land was leased, the buildings to the south of the church were demolished and the stones used in adapting the abbot's lodgings into a private house. The rest of the site was abandoned. In the 19th century the romantic aesthetic of the ruined abbey drew tourists and casual finds of window glass from this time were donated to Whitby Museum. In 1920 the site was handed over to the Work's Department (Thurley, 2013, p. 102).



A	1078	Whitby site granted to Benedictine monks
B	C12	38 monks
C	c. 1220-35	Building phase 1 choir and east end of church
D	1245-60	Building phase 2 transepts and east end of nave
E	c. 1310-25	Building phase 3 west end of nave, west and east ends of crossing tower
F	From 1325	Serious debts
G	1333/38	Use of fabric fund/fund raising
H	1380	Community numbers 20 monks. 1393, 21 monks
I	Early-mid-C15	Great west Window inserted
J	1538	Abbey dissolved, 20 monks

Figure 5.25 Timeline showing the fluctuating fortunes of Whitby Abbey (Atkinson, 1894; Rahtz, 1995; Clark, 1997; Coppack, 2006). See figure 5.3 for key

Archaeology

Between 1920 and 1925 the Government's Works Department cleared the site of rubble and debris to excavate the Norman church. As the excavation developed, the focus became the retrieval of material culture from the underlying Anglo-Saxon monastery. As a consequence, the recovery of finds from the 13th century buildings, including window glass, was less attentive and the site suffered from poor quality recording (Rahtz, 1995, p. 2; Coppack, 2006, p. 30). The location of most of the window glass is thus recorded as unstratified clearance layers in areas of the church, and in the area north of the church that is likely to be associated with church windows. The assemblage is now in the custody of English Heritage (EH) and the 19th century casual finds, as described above, are retained by Whitby Museum (WM). An English Heritage plan of the abbey is shown in figure 5.26

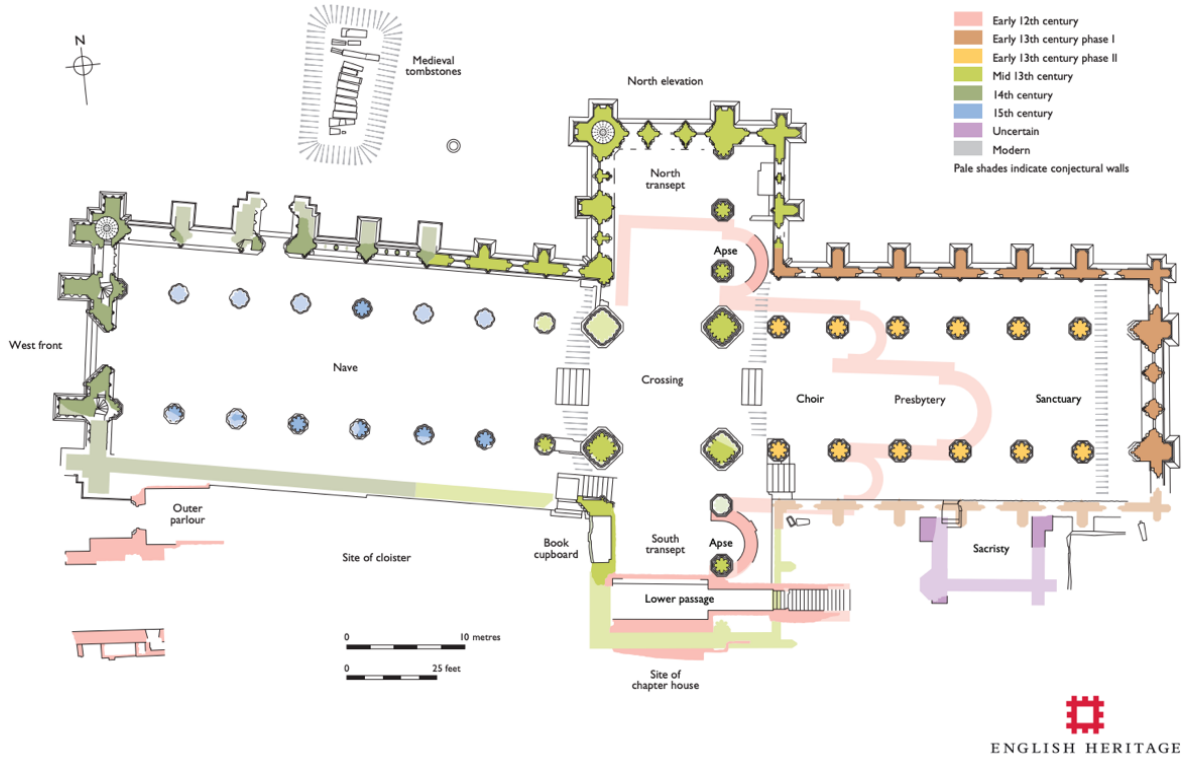


Figure 5.26 Plan of Whitby Abbey showing building phases. Taken from English Heritage, 2019, https://www.english-heritage.org.uk/siteassets/home/visit/places-to-visit/whitby-abbey/history/whitby-abbey-phased-plan.pdf

The Assemblage

A sub-set of 29 glasses was selected from the two assemblages held by EH and WM. These are dated 13th - 15th century with all but one of the earlier glasses acquired from EH (19 in total), and all 15th century fragments from WM (10 in total). Many of the earlier glasses have pitting and a brown to black weathered crust, in places flaking, yet the later glasses show only slight surface discolouration. Eleven fragments retain original grozed edges and discernible shapes include rectangular and diamond. Broad production is evident on four of the 15th century fragments. All coloured glasses are undecorated, these are streaky and flashed red, and two fragments of blue glass. Also included in the sample set are four plain fragments that are pale green and colourless. The sample glasses can be grouped into the following date ranges based on their applied decoration: the earliest group is mid-13th century and consists of motifs from the stiff leaf grisaille repertoire. The second group dates to the 14th century and decoration comprises micro-architecture, background rinceau and naturalistic border patterns. The third group is dated to the 15th century, and the decoration includes silver stained and stipple shaded micro-architecture and border patterns.

5.5.8 Summary of the archaeology for all sites

A summary of the excavations and retrieval of the study glasses, and the contextual information available at each site is presented in table 5.6. It is shown that the glasses were retrieved from some of the main buildings in the claustral range, the Chapter House, refectory, abbots lodgings and several areas of the church including the choir, east and west ends, north transept and the crossing. Outside of the main range, glass was retrieved only from the gatehouse chapel in the west of the complex at Bordesley. At Rievaulx three quarters of the glasses are from unstratified layers connected with the church, although 14 of the 58 glasses have findspots (approximately 25%). At Whitby around 62% are connected with the church, although unstratified and the remaining 38% of the glasses are 19th century casual finds.

5.6 Summary of the sites

Window glass was selected for the study from the seven high status monastic sites from four distinctive geographical areas distributed across England. Four Benedictine and three Cistercian abbeys were chosen so that window glass consumption between two contrasting monastic orders could be compared and interpreted. The glasses are dated from the late 12th century to the early 16th century and were deposited during or soon after the Dissolution of the Monasteries in the 1530s. A summary of the excavations and retrieval of the study glasses, and the contextual information available at each site is shown in table 5.6. Representative samples of the window glasses were selected for this multi-analytical study and these are described in chapter six.

Table 5.6 A summary of the excavations and retrieval of the study glasses, and the contextual information available at each site

Site	Excavation	Excavations	Assemblage size (approx.)	Sample set	Find spots	Contextual information	Archive
Alcester	Eastern range and refectory	Local archaeologists 1938	1214 Full catalogue Lead melting hearth in refectory	37	Chapter House	Lost	HE
Bardney	Church, ranges around the cloister	Antiquarian and commercial 1909-1915 & 2009	312 from refectory, unknown quantity from church Lead melting hearth in nave	23	W end & S aisle of church, N wall of refectory	Contextual information from unstratified (u/s) backfill (001)	Lincoln Archives
Bordesley	Church, E and SE church exterior, parts SE claustral range, gate chapel	Antiquarian, University, city council & MSC training scheme 1864 & 1967-1997	>1400 Lead-melting hearth in south transept	40	Church W end, choir, S transept, E end, gatehouse chapel,	Contextual information for whole site, BAR publications, site reports	Forge Mill Museum, Redditch
Hyde	Test pits at what is thought to be the abbot's lodgings	Community group in 2020	922 Full catalogue	48	Abbots lodging	Contextual information from test pits, site reports	Hyde900 community group
Louth Park	Most of monastic range	Antiquarian, second half of 19th century	967 Full catalogue	49	Unknown	Lost	C/o HE
Rievaulx	Site cleared	Works Department 1919-28	>4,000	58	N transept, NW door to cloister, Chapter House, W range	Sites notes lost except for some Illustrations and find spots	EH
Whitby	Site cleared & church excavated. Casual finds	Works Department 1920-25	463	29	U/s clearance layer of church and N of church, site field walking finds	Limited, u/s clearance in and around the church	EH & Whitby Museum

Chapter 6

6. Sample selection and methodology

6.1 Introduction

Research into the consumption of window glass at monastic sites was carried out on unpublished, excavated window glass from seven monastic sites in England. This material was deposited during the Dissolution of the Monasteries in the 16th century and collected during 19th, 20th and 21st century excavations. A sample set of glasses was chosen from each site for a multi-analytical study to investigate window glass consumption at the sites. A multi-analytical/interdisciplinary approach is used in this research using mixed methodology: archaeology, art history and history. Micro and macroscopic examination was undertaken to characterise the glasses physically and date them according to the applied decoration, and analysis using micro X-ray fluorescence spectroscopy (micro XRF) was conducted to group the glasses chemically and in some instances a provenance could be ascertained. For some of the glasses, the chemical composition was used to determine a broad date. The data from the analyses was then correlated with socio-economic and political events contemporary with the study period in order to understand the factors and events that might have influenced the consumption of window glass at the selected sites.

This chapter describes the material selection, the methodological choices adopted in the analyses of the glasses and the statistical methods used for the interpretation of the data.

6.2 Scarcity of window glass in the archaeological record

Window glass has been studied using an art history approach of extant, in-situ windows resulting in a reliable chronology of decorative motifs. Less attention has been paid to excavated material primarily due to difficulties interpreting the small and often degraded fragments, and thus it is a relatively unexploited source of primary evidence. Graves (2000) produced, however, a very comprehensive study of excavated window glass from the Gilbertine Priory of St Andrew in York. Nonetheless, examples of medieval window glass in the archaeological record are scarce. Its chemical composition makes it prone to deterioration and despite being made of commonly available raw materials, medieval window glass is only found associated with high status buildings. There is in addition, a general lack of historical documentation relating to the glazing of monasteries, such as purchase records or donation deeds. As a result, establishing a chronology of glazing at monasteries may be reliant on a synthesis of archaeological insights, historical information, compositional data and dating by proxy by comparing the fragments with extant windows.

6.2.1 The research material

Research material was acquired for the project from English Heritage, Historic England, local museums and archives, a university research excavation and a community excavation (table 6.1). Three full assemblages, from Alcester, Hyde and Louth Park were made available and were brought to the University of Sheffield for the duration of the study. The four remaining assemblages were assessed and a selection made at the storage facility. All assemblages were catalogued with the advice and expertise of Dr Rachel Tyson, glass scholar, and with help from members of the Hunter Archaeological Society and master's students from the Department of Archaeology at the University of Sheffield.

Table 6.1 Summary table showing the study sites, religious order, size of window glass assemblage held by various bodies who have loaned research material for the study, and the number of glasses selected for the study from each assemblage

Site	Religious order	No. fragments in assemblage	No. samples selected for study	Loaned by
Alcester Abbey, West Midlands	Benedictine	1214	37	Historic England
Bardney Abbey, Lincolnshire	Benedictine	312	23	Lincolnshire Archive
Bordesley Abbey, West Midlands	Cistercian	>1400	40	University of Reading
Hyde Abbey, Hampshire, South coast	Benedictine	922	48	Hyde900 Community group
Louth Park Abbey, Lincolnshire	Cistercian	967	49	Historic England
Rievaulx Abbey, North Yorkshire	Cistercian	>4,000	58	English Heritage
Whitby Abbey, North Yorkshire	Benedictine	463	29	English Heritage and Whitby Museum

6.2.2 Material selection

Representative samples from each homogenous group, as described above, were selected for the study. The rationale for selection was based on the following considerations:

1. Range of datable, decorative motifs and subjects
2. Date ranges: examples from each date range/glazing episode from the late-12th century to the early 16th century
3. Colour: examples of each coloured glass and examples of silver stained glasses
4. Plain glass: examples of undecorated glass, uncoloured and coloured
5. Forming technique: examples of broad and crown production where possible to see by eye
6. Some contextual information and find spots
7. Suitable condition: suitability for chemical analysis, glassy core visible
8. Permission to remove from store to undertake analytical work

The samples that were selected for the study were named according to a site code and sample number. The site codes are:

Alcester Abbey	ALC
Bardney Abbey	BA
Bordesley Abbey	B
Hyde Abbey	H
Louth Park Abbey	L
Rievaulx Abbey	R
Whitby Abbey	W

The numbers that were allotted are generally between 1 and 100 with some samples retaining their original catalogue number, for example ALC 0742.

6.2.3 Visual assessment

The glasses from each full assemblage that were in an as excavated state were washed as appropriate to their condition, then laid out at the University of Sheffield. They were examined visually and sorted into homogenous groups in order for a sample-set of characteristic glasses to be selected for the study. Glasses were sorted initially into groups according to colour, and then sub-grouped according to the style of the datable decorative designs present:

- Stiff leaf grisaille
- Other foliate motifs, rinceau, diaper and border patterns
- Figurative – faces, hands, feet, drapery
- Micro architecture
- Lettering

Further sub-groups were formed based on the broad date range of the motifs and stylistic features, for example, 13th century lettering, 14th century lettering, 15th century lettering; 14th century figurative, 15th century figurative, and so on. Undecorated, uncoloured glasses formed one group, and undecorated coloured glasses were grouped according to their colour. Red was further divided into streaky, striated and flashed for decorated and undecorated coloured glasses. Samples were chosen from each representative group. This number was limited to avoid sampling from the same window.

6.2.4 Assessing decoration and glass condition

Care was taken to select samples that were not too heavily corroded to the point where the glassy core could not be seen because a small region of unaltered glass was needed for the chemical analysis. However, where decoration was obscured due to the presence of a

weathered crust or surface concretions, a method was used to reveal the decoration. This involved shining raking (angled) light across the surface of the fragment to highlight the painted decoration. A photograph was taken of the fragment and uploaded into a digital drawing package called Procreate. This is a computer-aided mapping application that uses multiple layers to create an image. Where the decoration was still obscured, the photograph was edited within Procreate to improve the visibility of the painted lines without affecting the quality of the illustration. Some examples from the study are shown in figures 6.1 to 6.4 demonstrating the efficacy of this technique. This proved a quick and effective method of determining decoration at this selection stage. Subsequently all painted glasses from the project were illustrated using this technique in order to compile a corpus and to use as reference material for the stylistic analysis, which is discussed below (Appendices 63-69).

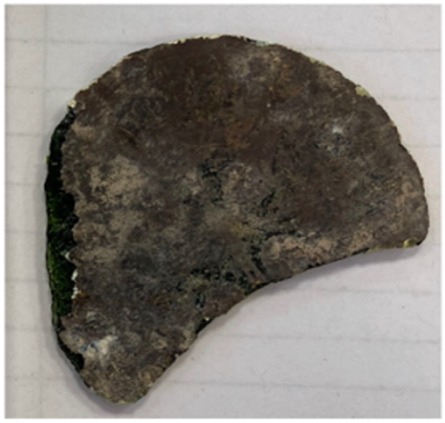


Figure 6.1 Working shot of ALC 57b showing heavily corroded surface and obscured decoration

Figure 6.2 Procreate illustration that shows clearly the decorative pattern despite the poor surface condition of the fragment of glass

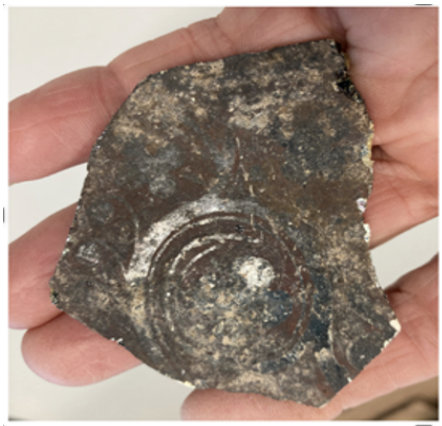


Figure 6.3 Working shot of ALC 49 showing heavily corroded surface and partially obscured decoration

Figure 6.4 Procreate illustration that shows the decorative pattern through the concretions on the surface of the glass fragment

A further technique, scanning micro-XRF, was used to image the design on a small selection of fragments from each assemblage and to investigate the composition of the paint used. This method uses a micro focus system and a moveable stage that allows the sample to be moved under the X-ray beam in order to scan the whole decorative surface. The machine maps the concentration of different elements, thus by selecting an element such as lead or iron that is used in the paint, an image of the design can be obtained, often despite surface weathering. It takes 30 minutes to map a fragment measuring 15 cm^2. Figure 6.5 shows the XRF image of ALC 41a mapping the element iron, revealing the decoration that is obscured by surface concretions (middle). Also shown is a working shot of the same fragment in reflected light (left).

Elemental maps were collected using a Bruker M4 Tornado at 50 kV and a 200 µA with a vacuum (20 mbar = 2000Pa). The analyses were conducted with a spot size of 20 µm and a spot distance of 200 µm. Two cycles were done for each map with a dwell time of 5 mm/s for each measure. Data processing was carried out using the Bruker M4 Tornado software. The XRF method is discussed further in this section (see 6.7.1). For this study however, this methodology was not widely used because it was time consuming, and the equipment was not readily available. The Procreate illustration of ALC 41a (Figure 6.5, right), when compared with the XRF map (figure 6.5, middle, taken from Dungworth, 2017) shows that although the technique was unable to reveal the decoration underneath the surface concretions (figure 6.5, left), it was nonetheless perfectly adequate for revealing enough of the decoration to date the glass by stylistic analysis (see section 6.2.4).

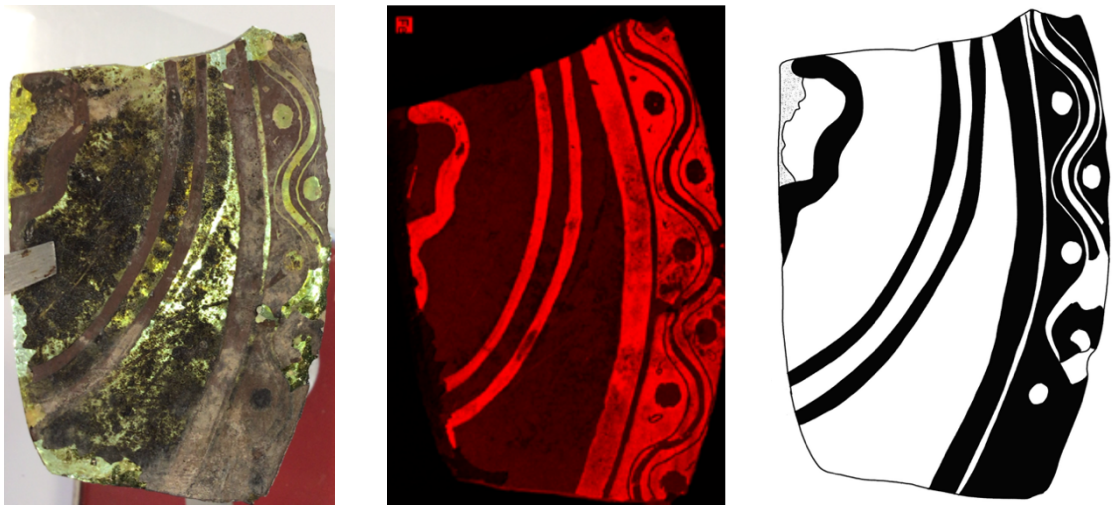


Figure 6.5 Left, working shot of ALC 41a from study in reflected light; middle, scanning XRF Image highlighting the iron in the paint to reveal fully the decoration (taken from Dungworth, 2017); right, the Procreate illustration from the study (also showing that some of the paint has flaked off post-excavation)

6.3 Analysis overview

Three analytical techniques were used on the samples: a stylistic analysis to date the glasses based on the applied decoration; technical, to understand the production technology and degree of corrosion of each sample and a chemical analysis to obtain a chemical composition to assign a tentative provenance to a broad area or country where possible

6.4 Stylistic analysis – stepped analytical approach

Decorated window glass can be dated through an examination of the style and characteristics of its applied decoration. In the project a staged methodology was used, firstly to assign a broad date range to each decorated glass, then increasingly refined through stage two and three resulting in, where possible, dated glazing episodes linked to evidenced events at each abbey.

6.4.1 Stage one – timeline

A broad date range can be assigned to types of decoration based on the time period for when they were in use. A visual timeline showing the chronology of designs from the study period, and datable glassmaking and glass painting techniques was created and used in the initial selection of the glasses; it was a practical tool to help speed up the sorting of a large number of fragments in an assemblage into date ranges. It was also used to ascertain potential glazing schemes where more than one decorative element coincided across the same time period.

The timeline was populated using information from published sources that include on-line catalogues and picture archives devoted to dated, in-situ stained glass windows in England (for example, Corpus Vitrearum Medii Aevi (CVMA), the Rose Window and Visual Arts Data Service (VADS)) and books detailing chronologies of stained glass windows (for example Baker (1978), Marks (1993)). The windows have been dated using documentary evidence and chronologies developed through art historical approaches.

A timeline tailored to each site was produced comprising only the range of decoration and techniques found in that sample set (see example from Bardney Abbey, figure 6.6). This was used to help refine the dating in stage three (below).

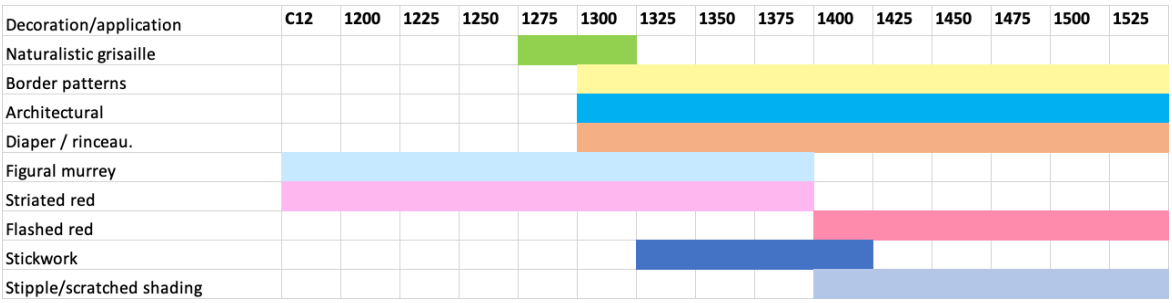


Figure 6.6 Timeline of some of the decorative elements found on Bardney Abbey samples, giving simplified dates of use. The timeline was used to help speed up the selection process and also used in stage three of the stylistic analysis (below)

6.4.2 Stage two - dated parallels

The dating of the glasses from each date range at each site was refined by combining the information from the timeline with dated parallels. These are well dated windows (from the same sources mentioned above) against which finer details in the sample glasses can be compared and the dating thus honed. Several examples of parallels were sought to enable a rounded approximation of the date of each glass, and the results presented in a spreadsheet for each site (Appendices 49-55). CVMA inventory numbers are included in the stylistic results tables for reference and where other sources were used, publications and page or plate numbers are listed.

6.4.3 Stage three - Evidence Informed Dating Framework (EIDF)

The EIDF graphic, which has been developed for the study, is a cross-reference of information whereby the timeline and information from the dated parallels (stage one and two) are correlated with relevant building work and documented historical events at each site to refine the dating of the glazing episodes. Not all glazing can be tied to building work or an event and thus some glazing episodes remain dated by way of the parallels.

The sequence for constructing the EIDF for each site is as follows:

- The background layer to the framework is the site-specific timeline of motifs and glass painting techniques showing broad date ranges when the decorative elements were in use
- The glazing episodes determined using the dated parallels are added to the framework
- Known building work and events at the abbey are added to the framework (from chapter five)
- The dates of the glazing episodes are adjusted to correlate date-wise with the relevant building work or event at the abbey
- The new date ranges for each glazing episode are presented in a table

An example of EIDF is presented below (figure 6.7) for Bardney Abbey.

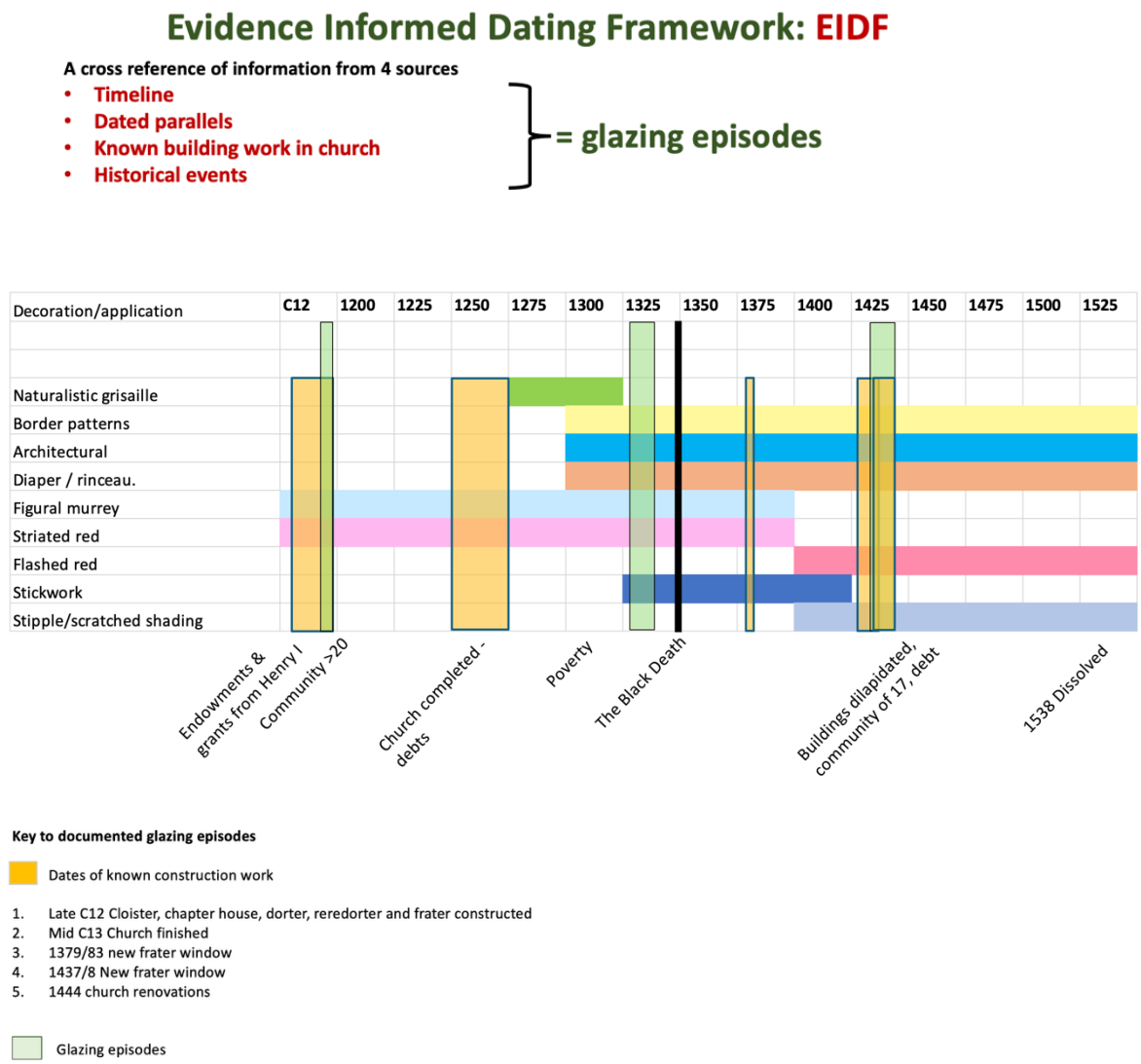


Figure 6.7 Evidence Informed dating Framework (EIDF) is a cross reference of information presented as a graphic to hone the glazing episodes at each site. It uses results from the timeline and dated parallels combined with historical and architectural information relevant to each site

6.4.3.1 Evaluation of EIDF

EIDF has been designed for this study to help refine the dating of the fragments of excavated glass, which, in the absence of, for example, purchase records would be dated more generally by their decoration alone. The success of EIDF lies with the validity of the historical information used to populate the dating framework. Accordingly, the evidence and historical information is taken from reliable sources. In this study, this includes original excavation reports, referenced secondary sources (at all sites) and personal communication with archaeologists and authors linked to the sites (for example at Hyde, Bordesley, Louth Park). BAR publications (British Archaeological Reports) were consulted for site details and descriptions of find-spots and building phases (for example at Bordesley).

Only relevant historical events and building phases/work are considered when aligning the glazing episodes. This results in as accurate a correlation as possible between the dating from stage one and two (timeline and parallels) and the historical and archaeological evidence. Building work includes documented accounts of building work within the abbey complex, window installations and archaeological evidence that shows the dating of relevant buildings in the complex. Historical events include published accounts of income generated through, for example the sale of holdings, and financial donations and other donations specifically connected with the funding of a window. Other secondary evidence that may support the use of EIDF include an awareness of the socioeconomic environment of the abbey such as documented times of affluence or poverty, or of local and national events that may influence the commissioning of a window installation. This can range from evidence of a fire (Hyde) or the appointment of a new ambitious abbot (Louth Park) to the outbreak of sheep scab that forced abbeys into debt (particularly the Cistercian abbeys).

EIDF is a useful tool that gathers multiple strands of evidence together and when used carefully can help fine tune the dating of some of the excavated glasses. In the absence of primary evidence such as purchase records that tie in directly to the excavated material, the revised dating obtained using EIDF is tentatively suggested.

6.5 Technical analysis

A visual inspection of all 284 fragments of glass from the project was undertaken. All glasses were examined macroscopically and microscopically to:

- Establish the physical condition of individual glasses and the extent of weathering
- Obtain accurate measurements of surface area and thickness
- Determine where possible original quarry shape and forming technique
- Determine the range of glass colours and any evidence of workshop practice that includes the presence of un-melted inclusions and toolmarks

The examination also noted the colour of the painted decoration, staining and the techniques used in the application of the paint. The information was compiled into a catalogue for each site (Appendices 56-62) and the data used to form a profile of the physical properties of the glasses as part of the technical analysis. The following section describes the factors that were documented.

6.6 Macroscopic analysis

Corrosion / weathering

The degree to which each glass has corroded, which can range from the formation of a weathered crust across the entire surface, to localised spots of corrosion, to relatively uncorroded/good condition, was recorded using abbreviations shown in the table 6.2. Corrosion is discussed in detail in section 2.5, where there are also examples from the study of different types of glass corrosion.

Table 6.2 Summary table of the terms and abbreviations used in the catalogue to describe the condition of each sample (see section 2.5 for examples of different types of glass corrosion encountered in the study glasses)

Condition	Description	Abbreviation
Uncorroded/good	Little or no corrosion	G
Corroded	Moderate signs of corrosion, localised spotting of dull, grey deposits of corrosion material	C
Severe corrosion	Glass is degraded with a weathered crust and/or flaking to reveal the glassy core	SC
Weathered crust	The dulled crust may extend over the edges of the glass demonstrating post depositional corrosion	WC
Lead shadow	A discoloured light or dark band on the edge of the glass where the lead came was attached	LS
Dulling	The loss of clarity and shine caused by the formation of a thin-spread of alteration product on the surface.	D
Pitting	In-situ weathering in the form of small cavities on the exterior of the glass that may be filled with dull, grey deposits of corrosion	P
Surface concretions	Collected from building materials, eg mortar and debris in the burial environment that stick in clumps to the surface	CS

Dimensions

The length, width and thickness of each glass was recorded in millimetres. It should be noted that thickness was difficult to measure accurately on glasses that are severely corroded as the surfaces have altered. A weathered crust, for example may increase the size of the glass in profile and conversely, a glass that has flaked will be decreased in size.

Evidence of forming process

Where evidence survived on the fragments, the forming technique used to make the window glass was recorded. The morphological properties that help identify forming technique in excavated glasses, either crown or broad are detailed in section 2.6 - for example, some pieces retained a straight fire-rounded edge (broad glass), or a pontil mark (crown glass). However, evidence for either technique was difficult to observe on small, excavated fragments to a large extent because of the size of the samples and the surface corrosion, as listed above.

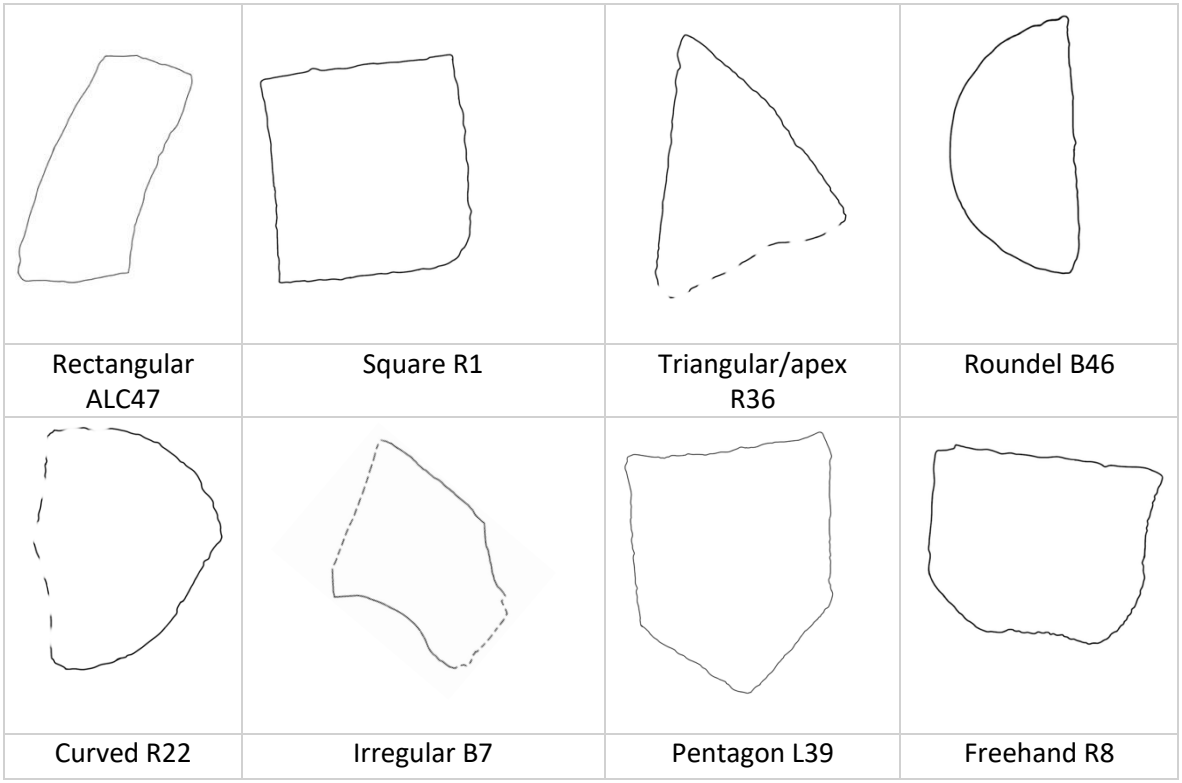
Surface morphology

The morphology of the glass surface was recorded to inform on features that may reflect some aspects of the workshop practice, such as tool marks, inclusions of un-melted batch or an uneven surface .

Quarry shape

Original quarry shapes were determined by an examination of the surviving grozed edges. These are the original edges fashioned by the glazier to shape the glasses when creating the panels. The shape may help determine how the quarries were used in a window and what type of decorative scheme is represented. A rectangular-shaped fragment may be a border or glazier's strip for example, or an irregular shaped glass may be a background quarry - both part of a figurative scheme.

The categories used to describe the original quarry shapes in the study are rectangle, square, triangle, diamond, roundel, freehand, irregular, pentagon and curved. 'Sub-' was added to the description of a shape that is not symmetrical, hence sub-square, sub-triangle. Irregular was used to describe a non-geometric shape, for example an 'L' shape. Freehand was used to describe an organic shape, for example the shape of a face or a foot. Examples of shapes from the study are shown in figure 6.8. A dotted line on the illustration denotes a broken edge



Rectangular ALC47	Square R1	Triangular/apex R36	Roundel B46
Curved R22	Irregular B7	Pentagon L39	Freehand R8

Figure 6.8 Examples of different quarry shapes from the study. Photographs of these and all other study glasses along with illustrations of all of the decorated glasses are found in Appendices 63-69

Even when a glass fragment is incomplete its original shape can be imagined by projecting the grozed lines, as seen in B7 (figure 6.8, second left, 2nd row), an irregular-shaped fragment with three grozed edges. Here the projected shape is not dissimilar to some of the background diaper quarries with the same decoration (CVMA 15852) and shows how the quarry may have been used (figures 6.9). This is explored more in the study where imagined schemes using fragments from the same glazing episode are suggested for each site (Appendices 19-25).

Figure 6.9 Left, the original shape of B7 from Bardney is estimated by projecting the lines of the grozed edges. Middle and right, it can be seen that the decoration and the shape of the glass is similar to a quarry in the east window at East Harling (CVMA 15852). Both are dated to the mid-15th century

Deliberate and natural colouring

The colour of the glass is important as it can provide information on technology, provenance, date, decorative styles and fashion. In the study the nomenclature used to describe glass colours are basic terms that cover a range of tones. It was difficult to be more precise because the hue is contingent on the thickness of the glass.

- The terms used in the project for naturally coloured glass are very pale green, pale green and medium green
- For deliberately coloured glass the terms used are red, blue, green, amber and murrey. Red glass was described as either streaky, striated or flashed (see section 2.4).
- Colourless was used to describe glass with no colour tint.

Paint

The glasses were examined visually to determine the paint colour, the techniques used to apply the paint and evidence of silver-staining:

- Paint colour was recorded as red brown or dark brown/black. Scanning XRF was also able to determine the composition of the paint in selected samples (see 6.2.4 above)
- The techniques used in the application of the paint such as smear and stipple shading (dabbing with brush), and linear stickwork (scratching the layer of paint away) were determined
- Silver stain, which was usually painted onto the exterior surface to provide highlights and depth was recorded (see section 4.4.3)

6.6.1 Microscopic analysis

A Keyence digital microscope was used to examine the micro-structure and surface features of selected glasses, capture high definition images at x20, x40, x50 magnification in 2D and 3D, and perform measurements. In the project it was used as follows:

- To photograph bubble alignment and measure the length and width of air bubbles
- Identify the method by which red glasses are coloured (streaky, striated or flashed)
- Examine more closely surface corrosion
- Examine grozed and fire-rounded edges, tool marks and surface morphology
- Create images of paint techniques and mosaic images of larger areas to examine surface morphology

Images were created using the instruments software and downloaded as JPEGs. Examples from the project are shown in section 2.5.2.

6.7 Chemical analysis

Chemical analysis was undertaken in order to establish the composition of the glasses from each site and establish groupings of glasses of similar compositions. Compositional data can be used alongside archaeological and stylistic evidence to determine the use of different raw materials and the changes in supply over time, trading patterns and regional variations. Provenance can sometimes be assigned by comparing the composition groupings with published compositional data from different regions or glass from glass production sites in England and Europe.

The technique used to determine the chemical compositions of the glasses in the study is micro XRF. This instrument was also used for elemental mapping, to characterise the chemical composition of the paint used in the applied decoration. Twenty seven samples were also analysed using a scanning electron microscope (SEM) with energy dispersive spectrometer (EDS) detector to verify the micro XRF findings by comparing the data from samples that were analysed both with SEM and micro XRF (see section 6.7.11 below).

6.7.1 Overview of micro-XRF

Micro-XRF is an analytical technique whereby elemental composition of a material is determined by measuring the secondary, or fluorescent X-rays that are emitted from a sample when it is excited by primary X-rays. As each element has a unique set of characteristic X-rays the compositions of a wide range of materials can be determined, including glass. Micro-XRF is a surface technique whereby the analysis occurs in the top few mms of the sample. The analytical technique has been used widely on archaeological materials including metals, soils and glass. For a more in-depth overview of micro XRF see Pollard and Heron, 1996, chapter two.

Micro XRF was chosen as the analytical technique in this study since minimal to no-invasive sampling was required (for example removing a small patch of corrosive layer), which was an important factor in the analysis of research material under the custodianship of museums and English Heritage stores. In addition, all fragments were small enough to fit into the desktop XRF chamber and analysis was rapid. This latter point was an important, practical factor in light of the large number of samples processed.

6.7.2 Limitation of techniques and mitigation strategies

The instrument can detect and measure major, minor and some trace elements. The technique is particularly reliable in measuring elements with a high atomic number, which generate more energetic X-rays. Lighter, low Z elements with a low atomic number such as sodium generate weaker X-rays that are more rapidly attenuated and so are more poorly characterised, even in a vacuum, which leads subsequently to a higher than ideal detection limit. This was the case for sodium where the detection was approaching 1wt%, and to a lesser

extent magnesium - unfortunately both important elements for the characterisation of the glasses. When grouping the glasses into types, the readings for these elements were checked for consistency as these were more likely to be reduced by the presence of corrosion crusts or poor focussing. A vacuum was employed to improve detection for low atomic mass elements. The software was set to calculate the chemical composition of the glass as oxides. The software provides a reasonable estimation using factory-set internal standards. However, a further set of glass standards were analysed in each run in order to estimate the reliability of all measurements in a complex matrix like glass; the reliability of the instrument; and also, to determine a correction factor for eight elements (see section 6.7.1).

6.7.3 Sample preparation

The limitations in the use of micro-XRF are noticeable in research into excavated window glass where poor surface conditions such as corrosion or concretions may produce results unrepresentative of the underlying bulk glass, because the method analyses the object's surface (see section 2.5). The analysed area of the sample must therefore be clean of surface contamination and also painted detail. Paint contains pigments that will be detected by the micro-XRF, usually heavy elements such as iron or lead that interact with the incident X-rays, which will affect the degree to which the glass composition beneath can be determined. For these analyses therefore, an area <5 mm^2 was prepared using a scalpel blade to remove upper sample layers containing corrosion products and surface concretions. The sample area was chosen to be discrete where possible, avoiding painted areas. The glasses were washed with distilled water and dried gently with absorbent paper. The location of the prepared sample area was recorded photographically to help locate it in the micro-XRF chamber, and also to inform any future studies of the glasses. Analyses with abnormally high concentrations of elements likely to be from corrosion such as sulphur, or with abnormally high levels of elements from the paint, such as iron or lead, were discarded.

Ideally, the sample should be homogeneous, flat and of a minimum thickness of between 1.5-2.0mm (Dungworth and Girbal, 2011) so that the object is 'infinitely thick' with respect to X-rays. Analysis of a surface that is not flat or homogenous may result in the unpredictable scattering of the secondary X-rays during analysis (see section 6.7.10) resulting in a low total (readings should nevertheless be close to 100%) and a less reliable analysis. To mitigate against this, three analyses were taken at different points across the same area of the sample and averaged. Results with abnormally low or high totals were discarded (see 6.7.10 below).

6.7.4 Instrument

A total of 284 glasses were analysed by micro-X-ray fluorescence spectroscopy using a Bruker M4 Tornado µ-XRF spectrometer owned and maintained by Historic England at Fort Cumberland, Portsmouth. The data were collected at 50kV and 200 µA from an area of 30 µm diameter in a vacuum for 120 seconds per analysis.

6.7.5 Selecting, identifying and quantifying elements

The following lists the elements that were measured for the study: chlorine, potassium, sodium, magnesium, calcium, strontium, rubidium, barium, titanium, zirconium, iron, manganese, cobalt, copper, zinc, alumina, silica, phosphorus, sulphur, lead, antimony and tin. These elements were found in previous analysis to be the best for characterising medieval forest glass so that compositional groups could be identified (e.g. Wedepohl and Simon, 2010).

A spectrum produced during analysis shows elemental concentrations as characteristic peaks and was checked for spectral interference. These may occur, for example, where the analyte's surface is uneven or where the fluorescent X-rays of two compositionally similar elements reach the analyser at the same time. This can result in a combined 'sum' peak. It was therefore important that all interferences were identified on the spectrum as they contributed to measurement uncertainty (a summary of the different spectral interferences are presented in appendix 18).

6.7.6 Standards, accuracy and precision

Reference standards of a known elemental composition are used in a chemical analysis to test the performance of the analytical instrument and the quality of the resultant data. This is to ensure that there are no major differences between measured and expected results for each sample for intercomparison. A range of standards were run during analysis over five sessions between 29/04/22 and 14/7/23, and at various times throughout each session to check for variation. Corning D, which best matches the expected compositions of the glasses under study, was run at every session, and other standards were also selected to cover the range of compositions in the glasses. Standards were run a total of 89 times (see Appendix 48a). An overview of each standard is shown in table 6.3 (full data in Appendices 34-47).

Table 6.3 The range of standards used in the study with an overview of the composition of each

Standard	Composition
Corning A	soda-lime-silica glass
Corning B	soda-lime silica glass with very high sodium (17%)
Corning C	high lead and barium
Corning D	forest glass composition
CL330	high sodium, magnesium, calcium
English Heritage EDXRF Tender 02	high calcium, silica and low sodium (0.86%)

6.7.7 Standards results

For each site, the measured averages of each element for each standard are reported with standard deviations (SD), relative standard deviations (RSD) and percentage error (%E) (Appendices 34-47). Sample HE2 is not a recognised standard; it is a post-medieval

archaeological glass sample that has been measured by different techniques at different laboratories, so may not be completely homogenous. This sample was included however, because its composition is very close to the material analysed in this study so provides a useful test of the methods.

Precision

Precision is expressed as relative standard deviation, which assesses the repeatability of the measurement, and calculated for each element a follows:
Standard deviation / average x 100

The main elements that were well characterised and precise to within 5% are potassium, magnesium, calcium, silicon, manganese, aluminium, phosphorus. The minor elements that were well characterised and precise to within 5% are cobalt, copper, lead, iron, strontium and titanium. Zirconium is precise to within 7%, and sodium and barium to within 10%. However, at lower sodium levels, e.g. 1.2% Na_2O in Corning D, precision worsens to 15% and, when analysing the uneven and potentially altered surfaces of the window glass itself, the sodium results are more severely impacted by corrosion layers or poor focus and often under-reported. The sodium data from this study are therefore only qualitative, but higher concentrations (>2wt%) were used with more confidence in the interpretation. The elements that are not precise are sulphur, antimony and tin. However, these results are generally for low levels of the element in the standards and are therefore thought to be acceptable here as semi-quantitative results indicating relative abundance. Rubidium was not precise (or accurate) and was not used. Antimony was sought but was not detected above the limit of detection. The quantification of antimony in the standards may have been affected by the thinness of the mounted standards being less than the infinite thickness for antimony under the measurement conditions in places. For some elements, such as chlorine, a lack of appropriate standards means the precision cannot be evaluated and these elements are used qualitatively.

Accuracy

Accuracy is expressed as % error (%E) and calculated for each element as follows:
%E= measured average – known / known x100

The main elements that were well characterised and accurate to within 3% are calcium, silicon and magnesium. Phosphorus, aluminium and sodium are accurate to within 5% but again this worsens rapidly at lower values. For Corning D, at 1.2% Na_2O, accuracy was around 5% on the mounted standards but, when analysing the uneven and altered surfaces of the window glass, the sodium results were impacted more than other elements and often under-reported. The sodium data from this study are therefore only qualitative, but higher concentrations (>2wt%) were used with more confidence in the interpretation. Potassium and manganese are

accurate to within 8%. The minor elements that are precise to within 3% are cobalt, copper and zinc and iron, lead, strontium and titanium are accurate to within 8%. The elements that are not accurate are barium, zirconium (present only in trace amounts), titanium, sulphur, tin, probably due to the low levels of these elements and peak overlaps with other elements in the glass. Rubidium, present in trace amounts, was not accurate and not used. Accuracy is worse for minor and trace elements in the standard Corning C (zinc, titanium, zirconium) because this is a lead and barium-rich glass, and the XRF quantification was not tailored for lead-rich glasses. For some elements, such as chlorine, a lack of appropriate standards means the accuracy cannot be evaluated and these elements are used qualitatively.

The average results for precision (RSD) and accuracy (%E) for all standards are presented in table 6.4. The standards results for individual sites are presented in (Appendices 34-47).

Table 6.4 The average results for precision (RSD) and accuracy (%E) for all standards

Normalised	**K2O**	**Na2O**	**MgO**	**CaO**	**SrO**	**BaO**	**TiO2**	**ZrO2**	**Fe2O3**	**MnO**
Precision average	1.85	9.70	4.16	0.74	3.53	9.52	2.19	6.75	0.78	0.38
Accuracy average	6.99	-7.23	0.96	-0.54	-5.12	32.04	-17.52	-220.37	-6.83	-7.99
Normalised	**CoO**	**CuO**	**ZnO**	**Al2O3**	**SiO2**	**P2O5**	**SO3**	**Sb2O5**	**SnO2**	**PbO**
Precision average	2.41	1.18	3.41	2.52	0.62	1.87	13.82	37.91	92.93	1.33
Accuracy average	0.53	1.43	2.94	0.41	0.44	-97.26	14.46	-136.64	49.34	11.22

6.7.8 Correction factors

There were eight elements where the disparity between known and measured was critical to determining compositional groupings; these elements are magnesium, alumina, phosphorus, potassium, titanium, copper, antimony and sodium, which were under-reporting at low amounts of the element. Different correction factors were calculated for these elements, for each site. A calibration curve was produced by plotting the known concentration in the standard against the measured value for each element of interest. Several standards with a range of data were used to create a robust calibration curve with multiple points. Although Hyde, Alcester and Louth have fewer data points on the calibration graph and fewer analyses in total, the corrections factors are nonetheless comparable to other datasets. For potassium, titanium, and copper the trendline went through the origin, but this was not the case for the lighter elements, magnesium, aluminium, phosphorus and sodium. For these elements the data were corrected in Excel so that more complex corrections could be used.

Table 6.5 shows the correction factors that were applied to the data. Measured = x, Actual = y. These factors are using uncorrected, normalised standards data.

Table 6.5 The correction factors that were applied to the data, where X = measured, Actual = y.

Site	Na_2O	MgO	Al_2O_3	P_2O_5	K_2O	TiO_2	CuO	Sb_2O_5 (unreliable)
Hyde	Y=0.9547x +0.3684	Y=0.9991x +0.5621	Y=1.0988x +0.4154	Y=1.141x +0.423	0.8425x	0.8039x	0.8912x	Y=0.9167 x-0.4292
Alcester	Y=0.8999x +0.3849	Y=0.9987x +0.5491	Y=1.3651x -0.4749	Y=1.0654x +0.4566	0.8257x	0.7822x	0.8881x	y=1.1796
Whitby	Y=0.8116x +0.9972	Y=1.0133x +0.4829	Y=1.0942x +0.4736	Y=1.0821x +0.5158	0.834	0.7295	0.9171x	Y=1.0682x +0.3708
Rievaulx	Y=0.8464x +0.803	Y=1.0666x +0.4545	Y=1.1306x +0.1936	Y=1.0872x +0.4221	0.8413x	0.8363x	0.9067x	Y=1.6503x +0.3555
Louth	Y=0.86x+0 .6874	Y=0.9727x +0.664	Y=1.0832x +0.6347	Y=1.0567x +0.4515	0.8189x	0.7943x	0.7353x	Y=1.0805x +0.04
Bordesley	Y=0.8206x +0.829	Y=1.01318x +0.4152	Y=1.1528x +0.2654	Y=1.0642x +0.4842	0.829x	0.8637	0.8861	Y=1.5548x +0.4568
Bardney	Y=0.841x+ 0.8337	Y=1.0735x +0.3444	Y=1.1538x +0.2859	Y=1.0861x +0.4946	0.834x	0.8352	0.9053x	Y=2.1227x +0.2174

6.7.9 Detection limit

The limit of detection (LOD) is the minimum amount of an element that can be detected and quantified in a compositional analysis. This lowest limit must be higher than the inherent statistical noise of the micro XRF instrument that is associated with the X-ray production process. Below this is reported as below limit of detection (<LOD). The limit of detection for each element is thus contingent on the individual analytical tool.

The limit of detection for each element was calculated at 3.3 times the standard deviation of the measurements for that element using a range of reference standards of different compositions (Corning A,B,C and D) in order to plot a robust calibration curve (Magnusson and Ornemark, 2014). This was conducted as follows:

- A calibration curve was plotted with the known concentrations of the standards on the X-axis and the measured concentrations of the standards on the Y-axis
- Regression analysis was carried out using Excel regression function. This gave the coefficients, which included the slope value and the standard deviation of the Y intercept.

The limit of detection for the significant elements in this project were calculated and are reported in figure 6.6. The limit of detection of some elements, such as lead and copper are reported higher than calculated using the regression line as suitable standards were not available.

Table 6.6 Limit of detection for the significant elements in the study

Limit of detection	
Na2O	0.88
MgO	0.26
Al2O3	0.65
P2O5	0.59
K2O	0.42
TiO2	0.12
MnO2	0.10
Fe2O3	0.08
CoO	0.01
CuO	0.11
Rb2O	0.05
SrO	0.01
ZrO2	0.02
Sb2O5	0.91
PbO	0.27
ZnO	0.01
BaO	0.15
SnO2	0.22
SiO2	1.78
CaO	4.37
SO3	0.26
Cl	

6.7.10 The Data

The tabulated results are calculated averages of the analyses with data processing carried out using the Bruker M4 Tornado software. The measured data were checked: totals between 90 and 103% were considered acceptable but between 70-90% and 103-110% judgement was required whether to use the data, for example, if the measured amounts of the three points (for each sample) were very similar despite some differences in the totals. Data with totals < 70% and >110% were discarded. The data were then normalised to 100% so that data can be compared, the correction factors were applied, the data were recalculated and normalised again to 100%. There were several reasons to apply the factors to normalised data (instead of raw data) that related to the use of a surface analytical technique. Medieval glass invariably has an uneven surface and there is a possibility of spectral interferences caused by the scattering of secondary X-rays. In addition, the micro-XRF instrument is manually focussed, thus operator errors in focussing the instrument itself may result in a lower or higher total amount of data collected, expressed as a percentage (as described above). After correcting, the data were normalised a second time to 100% so that they could be compared. The results

are viewed as semi-quantitative because of the limitations described above, in particular the heterogeneity, irregular surface, and the surface alteration and contamination of the objects.

The following chapter seven reports the results from the micro XRF analysis. Because of the limitations of micro XRF regarding the detection of the lighter elements such as sodium (as discussed above), a small group of samples were also analysed using another analytical technique, SEM (scanning electron microscope) to compare results, and determine which elements were best for use in the study. It was found that potassium, calcium, silicon, manganese and magnesium were well characterised using micro XRF (after applying the correction factors) and these elements were used to determine groupings of glasses for each site. The elements that were not used as discriminators were rubidium, strontium, zinc, titanium, zirconium and lead. The colourants copper, cobalt and iron were not used to discriminate groupings but were used to determine how the coloured glasses were coloured. Chlorine was used with sodium to determine the possible use of salt (NaCl) in production. Unfortunately, many of the analysed medieval glasses contain low levels of sodium of around 1wt%, and at these concentrations both the precision and accuracy for sodium by XRF are poor. Comparing the SEM and XRF results also demonstrated that when analysing the uneven and altered surfaces of the window glass, sodium was often under-reported by XRF. Sodium values were therefore used qualitatively and only higher levels (>2%) were used in the interpretation. Antimony, sulphur and tin are difficult to detect at low levels with SEM so were not used.

6.7.11 Scanning Electron Microscope

Selected glasses were also analysed using scanning electron microscope (SEM) with attached energy dispersive spectrometer (EDS). This was to verify the micro XRF findings by comparing the data from samples that were analysed both with SEM and micro-XRF. The advantage with this technique is that SEM gives a high magnification image of the sample at the same time as analysis takes place. In the SEM image, corroded or painted areas can be differentiated clearly from unaltered glass in back-scattered imaging mode (which shows areas with different compositions as different greyscale shades). Small areas of the unaltered glass can then be targeted for analysis with the EDS system. The technique is, however, destructive. Permission was given for small chips of glass from 27 samples in total from Alcester, Bardney, Bordesley, Hyde and Louth Park to be taken from the edges of the larger fragments and mounted for analysis as representative samples.

6.7.11.1 SEM methodology

Small chips of glass approximately 2-3 mm^2 were embedded in epoxy resin blocks with the fresh fracture at the surface. The surface of the block was ground flat using increasing grades of carborundum paper and polished to a 1 µm surface finish with diamond paste. The block was vacuum-coated in carbon to disperse charge build-up during analysis. The samples were analysed using an FEI InspectF SEM (analytical conditions, 25kv (kilovolts) and 1.2nA (beam

current)fitted with an Oxford X-act X-ray detector. Spectra were acquired for 200 seconds at spot size 5 nanometres (nm) from multiple spots on each sample and the results averaged. Correction factors were applied to five elements: sodium, aluminium, silica, phosphorus and copper (above, section 6.7.7).

6.8 Compositional groupings

Scatterplots were used to establish and visually represent compositional groupings of glasses from each site using discriminating elements, or variables. The plots show the ratios of the concentrations of the variables using the data from the micro-XRF analysis. It was difficult to determine some discrete compositional groupings (where there were few compositional differences) and thus multiple biplots were required to establish the groupings. In some cases, discrete groupings could not be determined and principal component analysis (PCA) was used to differentiate between compositional groups.

6.8.1 Principal component analysis (PCA)

Principal component analysis extracts the significant information from a multi-variate data set by reducing each data point into the principal components, usually first and second dimensions. PCA was therefore useful in this study because of the large amount of data generated by the micro-XRF analysis: 284 samples each with 22 elemental variables. PCA was used as a complimentary tool alongside the scatterplots to test the groupings established by the scatterplots and to help assign provenance by cross matching the data from the groupings with the regional data, see chapter eight

6.8.1.1 PCA methodology

To study the provenance of the glass fragments, starting from the normalised, corrected micro-XRF data collected from the glass fragments PCA was applied on the elements potassium, sodium, magnesium, calcium, silica, manganese, iron, alumina and phosphorus, using R software. These elements were selected to account for the major and minor elements routinely used in medieval window glass analysis and to enable comparison with regional data.

The PCA was done by using the inbuilt ‘stats package’ in R function princomp. The data were centred and scaled before the analysis, and the coordinates on each principal component were calculated. Only the loadings for PC1 and PC2 were considered, which accounted for an average of 62% of the variability in the data (average of 6 measurements, Appendix 17). Using PCA and biplots in tandem proved a comprehensive method of establishing the groupings.

6.8.2 Grouping the data

The compositional data for each site was compiled into a spreadsheet and colour coded according to date range and compositional sub-group, as determined using the biplots and PCA (above).

The same system of colour coding was used throughout the study for each date range and compositional sub-group within each date range, these are: 12th century, pale grey; 13th century, yellow; 13th/14th century, blue; 14th century, green; 14/15th century, mid grey; 15th century, pink and 16th century, dark grey. The compositional sub-groups within each of these date ranges are labelled, for example as C13a, C13b, C13c, C14a and so on, and are colour coded using one of three different hues of the relevant colour for the date range. This is shown in table 6.7. There is only one compositional group in the 12th, 13th/14th, 14/15th and 16th century date ranges at any of the sites.

Table 6.7 The compositional data for each site was compiled into a spreadsheet and colour coded according to date range and compositional sub-group as indicated in the table

Dated sub-group	Colour code
C12	
C13a	
C13b	
C13c	
C13d	
C13/14	
C14a	
C14b	
C14c	
C14d	
C14e	
C14/15	
C15a	
C15b	
C15c	
C15d	
C15e	
C16	

6.9 Summary of research methods

Glasses from seven monastic sites were analysed using a multi-analytical approach to date each glass fragment, establish their physical characteristics and obtain compositional data to determine regional provenance.

To date the glass, a three stepped approach was used that employed a timeline, dated parallels, and EIDF, which was devised for the study to hone the dating. Raking light was used to reveal obscure decoration and each decorated fragment was drawn using Procreate for reference in the stylistic analysis. For the technical analysis a macro and microscopic examination of each fragment was undertaken to characterise the physical qualities of each glass. Measurements and descriptions including forming technique, colour and thickness were taken and compiled into a catalogue. Because of the large quantity of samples in the study, micro XRF was used for the chemical analysis. There were limitations to this technique and some lighter elements were poorly measured, thus correction factors were used and data was normalised to mitigate against the uneven surfaces of the analyte and any errors with the manual focussing. The results are semi-quantitative but were corroborated with SEM data from selected samples and found to be compatible. The identification of compositional groupings at each site used scatterplots, and PCA as a complimentary tool to test the groups. PCA and scatterplots were also used to determine a tentative provenance by cross matching the data from the groupings with regional data.

The characterisation of each glass using the data from each analytical technique is used to examine the nature of glass consumption at high status sites represented by the seven monastic sites in the study. The results chapter will present the results from the analyses for each of the seven sites.

Chapter 7

7 Presentation of results

7.1 Introduction

This chapter presents the results from the stylistic, chemical and technical analysis of the 284 glass samples from the seven study sites: Alcester, Bardney, Bordesley, Hyde, Louth Park, Rievaulx and Whitby. The results of the analyses are presented on a site-by-site basis with the following information presented in the Appendices: stylistic descriptions (1-7); dated parallels of each decorated glass (49-55); technical analyses (56-62); illustrations and photographs of each sample (63-69). The provenance of the glasses is reported in chapter eight. Each Evidence Informed Dating Framework (EIDF) is customised for the sample set of glasses from each site. The data from the chemical analysis is used in scatterplots to determine groupings of glass with similar compositions from each site. The discriminating elements for each grouping are presented in a table for each site with standard deviations and the full data set collected is presented in Appendices 26-32. The compositional groups are not defined by a single element but by looking at a combination of elements and thus the range of elements shown in each table varies between sites.

7.2 Alcester

7.2.1 Results of stylistic analysis

There are 37 samples of glass from Alcester dated using the timeline of decorative motifs to the broad date ranges, 13^{th,}, 13th/14th, 14th, and 15th/16th centuries. Thirty-three glasses are decorated, while four are plain.

13th century

There is one group in the 13th century date range comprising 15 fragments: 12 are decorated, of which five are coloured, amber and streaky red, and three are plain. The glasses represent two distinct window styles, monotone grisaille interspersed with coloured quarries, and a biblical themed style represented by the Lombardic lettering.

Stiff leaf grisaille decorative motifs, seen on one third of the fragments, comprise trefoils with curling stems on a cross-hatched background. There are similar arrangements at Lincoln Cathedral, dated 1220-25 (CVMA 217), Salisbury Cathedral, dated to the early to mid-13th century (CVMA 9954) and local churches such as West Horsley, where the windows are dated

1210-25 (Marks, 1993, p. 139). The berry motif (ALC 6) is seen up until the third quartile of the 13th century and it is unusual that the berries are straight off the stalk without leaves or lobes. The parallel from York Minster, dated 1220-25 shows both fruiting leaves and stalks (figure 7.1). ALC 65a is a streaky red quarry that would have been interspersed throughout the panel to add a spot of colour in an otherwise monotone scheme. ALC 73c is a coloured fragment and although no direct parallel is found, the example from York Minster Chapter House, while dated to the late 13th century, demonstrates how the glass may have been utilised (CVMA 3657).

There are two amber-coloured glasses with Lombardic letters that make up the words 'Rex' and 'Ezechias' and one amber-coloured glass with a single letter 'u'. They are similar to biblical designs from Canterbury Cathedral featured in the Genealogy of Christ and the Tree of Jesse from the early 13th century (Michael, 2019, p. 131, 133, 139. King (Rex) Ezechias or Hezekiah (the spelling varies in historical references) from the Old Testament was a king of Judah and the lettering would have been incorporated into a pictorial window in a similar fashion to the Canterbury parallels (Michael, 2019, figure 7.2). Examples of windows that feature both grisaille and biblical themes are seen at Lincoln Cathedral although these are 18th century re-arrangements of fragments from different 13th century windows (Morgan, 1983, p. 1).

13th/14th century

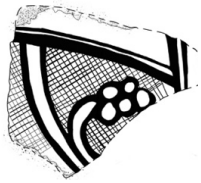
The single 13th/14th century fragment with a naturalistic leaf can be compared with late 13th century motifs from York Minster (CVMA 21247, figure 7.3) and early 14th century motifs from Eaton Bishop (CVMA 2909). The Alcester motif is more upright than both of these parallels but they are veined in a similar manner. The design is part of the grisaille repertoire with a plain background.

14th century

There is one chronological group dating to the 14th century comprising 20 glasses: 19 are decorated, of which six are silver-stained and seven are coloured, blue, green, striated red, amber and murrey. Many of the parallels seen in this group are dated to the second quartile of the 14th century, these include Tewkesbury, dated to the mid-14th century (e.g. CVMA 1754), Eaton Bishop that dates to 1330-35 (for example CVMA 14742) and Hadzor, dated to around 1340 (https://stainedglassmuseum.com/history). This window is used to suggest an imagined scheme for the 14th century glasses from Alcester (Appendix 19).

There are two fragments with figurative decoration: ALC 90 compares directly with the Annunciation to the Virgin from Hadzor in the style of drapery, the slight 'S'-shaped stance and the orans position of the hand (https://stainedglassmuseum.com/history, figure 7.4). ALC 75 is a forward-facing head; a parallel design from Waterperry is dated to the early to mid-14th century, and although side facing is styled in the same manner particularly the eyebrows, mouth and hair (CVMA 9982, figure 7.5). It is probable that the figures were placed within an

architectural canopy although there are no depictions of architecture in this group of 14th century glasses.

Figure 7.1 Illustrations of the Five Sisters window, York Minster by John Browne; Winch, Vidimus 143, 2023		ALC 6 
Figure 7.2 Michael, 2019, p. 41 Canterbury Cathedral		ALC 47
Figure 7.3 CVMA 21247 York Minster		ALC 93
Figure 7.4 Stainedglassmuseum.com Hadzor.		ALC 90
Figure 7.5 CVMA 9982 Waterperry		ALC 75
Figure 7.6 CVMA 25255 Margaretting		ALC 43

Half of the glasses are decorated with background and border patterns of repeating diaper and rinceau motifs, birds and other natural forms, and drolleries. These latterly include depictions of demonic creatures such as ALC 74, and ALC 42b, which is silver-stained, and one parallel is the Abraham panel of the Tree of Jesse at Wells Cathedral, dated to around 1340 (b4, The Rose Window).

15th/16th century

The single sample in the 15th century date range depicts a Gothic letter 'm'. It is more cursive than earlier Gothic lettering and thus is similar to lettering from Margaretting (CVMA 5018, 25255, figure 7.6) and East Harling that date to the second half of the 15th century (CVMA 15867), and Waterperry that dates to 1527 (CVMA 5224).

Table 7.1 shows that the Alcester glasses represent four glazing episodes from the first half of the 13th century, 13th/14th century, the second quartile of the 14th century, and 15th/16th century.

Table 7.1 Alcester Summary of dating by parallels

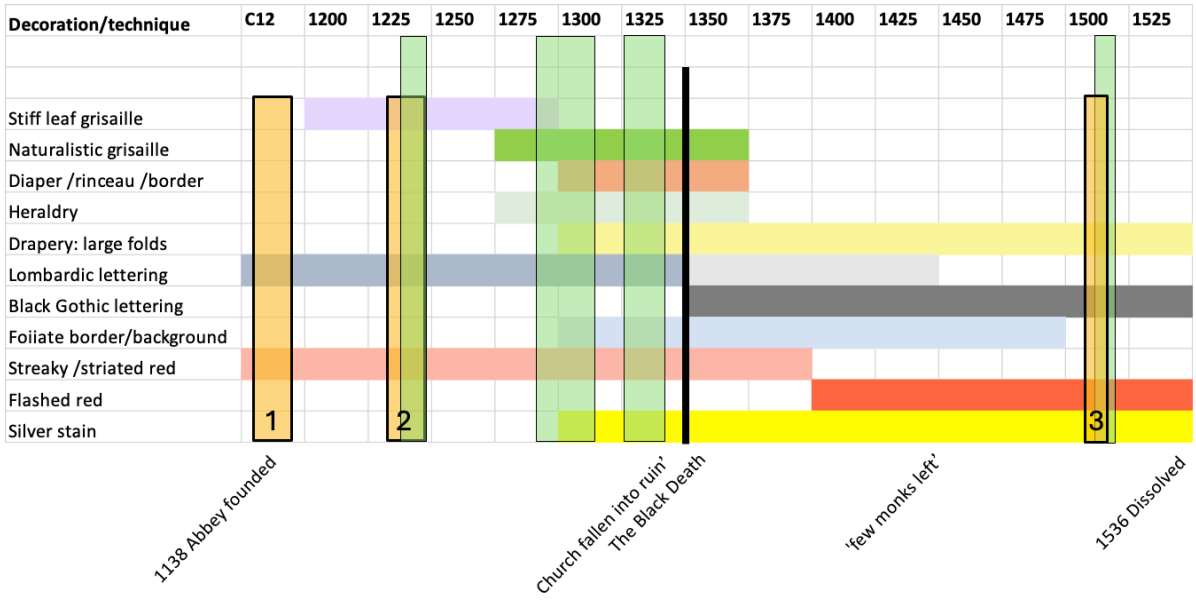
Date range	No. samples	Stylistic dating
C13	15	First half C13
C13/14	1	C13/14
C14	20	Second quartile C14
C15/C16	1	late C15/early C16

7.2.2 Refined dating using Evidence Informed Dating Framework (EIDF) for Alcester

Using EIDF, figure 7.7, the dating of the glasses may be further refined by correlating with relevant building work at the abbey (table 7.2).

- The 13th century glasses may be refined to around 1238 to align with the date of the Chapter House
- There is no documentary or archaeological evidence of building work that coincides with the glazing episodes that are dated 13th/14th century and the mid-14th century, thus the dating of these two episodes remains unchanged. Judging by the poor state of the abbey's finances at this time it is possible that these were donor windows (see section 4.4.3)

- The ruined church was rebuilt around 1515 following a long period of decline (Minutes, 1939, Birmingham Museum Archives; Rahtz and Hirst, 1976) and based on the likelihood that the Chapter House was rebuilt at the same time the single 15th /16th glass can be refined to this date



Key

Dates of known construction work

1. 1138 abbey built
2. C. 1238 Church, refectory and Chapter House reconstructed
3. 1515 Ruined church reconfigured

Glazing episodes

Figure 7.7 Alcester Evidence Informed Dating Framework

The revised EIDF dating of the Bordesley glasses are shown in table 7.10

Table 7.2 Alcester The revised dating of the glasses using EIDF

Date range	No. samples	Revised EIDF dating
C13	15	c. 1238
C13/14	1	C13/14
C14	20	Second quartile C14
C16	1	c. 1515

7.2.3 Technical results for Alcester

Glasses from all date ranges show evidence of both post-depositional and in-situ weathering. The latter is evidenced by way of exterior pitting and demonstrates that many of the glasses were decayed while installed in the windows (although this may have been shown as minor surface dulling at the time and exacerbated in the burial environment). The poor condition means that there are only five glasses from the Alcester groups where evidence of forming technique can be observed: these are broad glasses, one dated to the 13th century (ALC 73c) and four to the 14th century (ALC 57b, 60, 68, 41a). The tool marks found on ALC 65a (13th century) show that the glass was manipulated while still soft perhaps during the opening up stage of broad production. ALC 53 is interesting in that the paint has flaked away from the glass leaving a palimpsest of the design on the glass (see figure 2.5, section 2.5.2). R2, from Rievaulx Abbey is also a green glass degraded in a similar manner and it is possible that in both samples the paint has protected the glass underneath from decaying thus leaving a raised impression of the decoration (Graves, 2000, p. 398).

Twenty four of the 25 naturally coloured fragments are pale green; only the single 16th century glass is colourless (ALC 43). This may have been an intentional choice for this glass, so as to be seen clearly in the Chapter House, as it is painted with a letter 'm' and may originally have carried a bible passage or a donor's name. The original quarry shapes dated to the 13th century are limited to straight and curved rectangles that are painted with inscriptions, for example ALC 47. In the 14th century the range of shapes was expanded to include triangular (ALC 61) and freehand (ALC 90). The range of colours also expands from red and amber in the 13th century to include murrey, blue and green, plus silver stain in the 14th century. There are no 15th century glasses from Alcester and there are no surviving original edges on the 16th century glass to suggest a quarry shape. From the 13th to the 16th century the quarries decrease in thickness from an average of 3.7 mm to an average of 2.0 mm. This demonstrates an increasing finesse over time that is seen at all other sites in the study and may relate to increased use of broad glass.

7.2.4 Compositional results for Alcester

All 37 glasses have a forest composition and the discriminating elements that best show the different groupings for Alcester are potassium, calcium, sodium and silica. The scatterplots of potassium oxide (K_2O) vs. calcium oxide (CaO) (fig 7.8) and potassium oxide vs. silicon dioxide (SiO_2) (fig 7.9) show that there are four compositional groupings, one in each of the date ranges, 13th, 13th/14th, 14th and 16th century. In two of the plots (figures 7.2 and 7.3) the single 13th/14th century glass (ALC 93) plots close to the 14th century glasses with similar levels of potassium, calcium and silica, but this fragment is distinctive due to the high level of sodium (3.42%). The limit of detection for sodium is 0.88% but amounts over 2% are used. A PCA bi-plot that was produced shows similar groupings (Appendix 10).

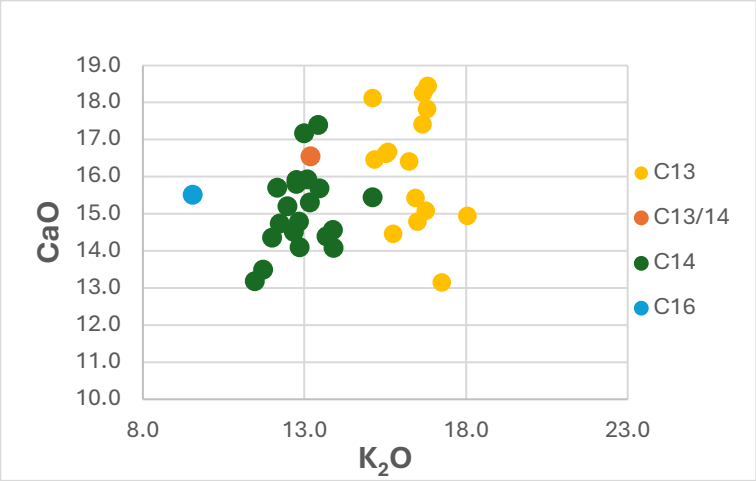


Figure 7.8 Alcester Plot of potassium oxide versus calcium oxide

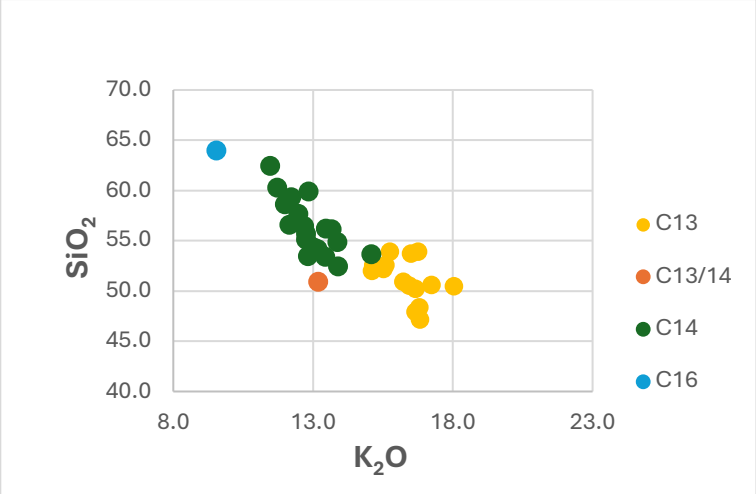


Figure 7.9 Alcester Plot of potassium oxide versus silicon dioxide

7.2.5 Compositions for all groupings in all date ranges

The average amount of each discriminating element and standard deviations are shown in table 7.3.

Table 7.2 Average wt% of main discriminating oxides with standard deviations (SD) for Alcester

Group	No.	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	Al_2O_3	SiO_2	P_2O_5	CaO:K_2O	Coloured samples
C13	**15**	**16.4**	**0.88**	**0.28**	**5.5**	**16.3**	**0.81**	**1.52**	**51**	**5.4**	**1**	**5**
SD		0.8	0.27	0.41	0.85	1.59	0.07	0.28	2.14	0.67	0.12	
C13/14	**1**	**13.2**	**3.4**	**0.41**	**5.93**	**16.53**	0.95	1.96	**50.87**	4.62	**1.25**	**0**
C14	**20**	**12.9**	**1.13**	**0.27**	**4.6**	**15.07**	**1.00**	**2.54**	**56.18**	**4.0**	**1.2**	**7**
SD		0.85	0.40	0.06	0.88	1.09	0.17	0.53	2.70	0.46	0.09	
C16	**1**	**9.56**	**0.50**	**0.23**	**4.47**	**15.50**	**0.46**	**0.74**	**63.9**	**2.63**	**1.6**	**0**

13th century

Table 7.3 shows that the glasses from the 13th century grouping are characterised by high amounts of potassium, magnesium, calcium and phosphorus, and a low amount of silica (compared with average compositions for other glasses in the study for this date range). Two glasses, ALC 12b and ALC 14 are probably from the same sheet as they have near matching compositions. The chemistry of the five coloured samples is tabulated in the table 7.3.

13th/14th century

The single glass in the group is compositionally very similar to the 13th century samples except for a lower amount of potassium and a higher amount of sodium (table 7.4).

14th century

Table 7.3 shows that the glasses have low levels of potassium, magnesium and phosphorus. The chemistry of the seven coloured samples is tabulated below, table 7.4.

16th century

There is one sample of 16th century glass that has low amounts of potassium and phosphorus. The very low concentration of aluminium suggests the use of a pure sand source.

7.2.6 Colour

The five amber glasses are coloured in a reducing furnace atmosphere, or the batch included carbon-containing materials such as woodchips, coal or charcoal (Paynter and Jackson, 2018). The blue glasses are coloured with small amounts of cobalt and because there are also small quantities of copper, zinc and lead it is probable that brass filings together with a cobalt source were added to the batch. The green glasses have copper and lead suggesting the addition of some form of copper alloy, possibly scrap metal. The single murrey glass is coloured with high amounts of manganese in an oxidised form. The red areas of some of the streaky and striated red glasses were not analysed in order to characterise the base glass composition so that provenance could be ascertained. The following table 7.4 is a summary of how each of the intentionally coloured glasses is coloured.

Table 7.3 Summary table of coloured glasses and the colourants and techniques used to make the different colours

Colour	Colourant	Samples	Date range	Information
Streaky red	Red not analysed	ALC 65a	C13	Kunicki-Goldfinger type A (2014)
Striated red	CuO (0.5%)	ALC 60	C14	
	Red not analysed	ALC 61		
Amber	Reducing atmosphere, possibly carbon added	ALC 44, 46, 47, 73C ALC 68	C13 C14	May have contained carbon-containing materials (Paynter and Jackson, 2018)
Murrey	Coloured by MnO (1.63%) in an oxidised state	ALC 75	C14	
Blue	CoO (0.07%) and Cu (0.3%) CuO (0.20%) and Zn	ALC 49	C14	Cu, Zn, Pb indicates the possible addition of a Cu alloy such as brass (Gratuze, Pactat and Schibille, 2018)
Green	CuO (2.7% and 2.3%)	ALC 53, 57b	C14	Both of these samples have significant levels of Zn, Pb and Sn suggesting added scrap Cu alloy, as above

7.2.7 Cullet

There is evidence for the introduction of coloured cullet to the batch in three of the 13th century non-coloured samples (ALC 742, ALC 748, ALC 897); these glasses, which are all undecorated, contain trace amounts of lead, copper and possibly cobalt. There is no clear evidence of added coloured cullet in the 13th/14th century glass, but in the 14th century group, several non-coloured glasses have significant amounts of copper and lead to suggest the inclusion of cullet (that is contaminated by colourants) to the batch: these are six silver-stained glasses (ALC 41, ALC 41a, ALC 42, ALC 42b, ALC 80, ALC 92) and all of the painted glasses excluding ALC 91. ALC 74 is a non-coloured glass that contains 0.21% copper. Lead, present in eight glasses may have entered the batch through the inclusion of lead came attached to recycled window glass, or through window glass that has painted decoration using lead paint. The 16th century glass shows no evidence of contamination from coloured cullet.

7.2.8 Summary of results for Alcester

The first episode comprises 15 glasses that are dated to around 1238 when the abbey was re-built. The pale green fragments are thick and decorated with stiff leaf grisaille motifs and the thinner, amber coloured fragments are painted predominantly with Lombardic lettering. There is evidence in the composition of the addition of coloured cullet in the three non-coloured glasses.

The second episode consists of a single glass that is dated using parallels to the 13th/14th century. It is pale green, moderately thick with an un-even surface and decorated with a grisaille motif.

The third episode comprises 20 forest glasses that are dated using parallels to the second quarter of the 14th century. The group comprises pale green and deliberately coloured glasses - murrey, amber, striated red, blue and green and the compositional evidence suggests that coloured cullet may have been added. There is one plain glass, and the remaining glasses are painted with a range of motifs commonly found in figural schemes. The glasses show evidence of broad production. Six of the pale green glasses are silver-stained.

The fourth episode is represented by a single fragment of forest glass dated to around 1515 when the church and presumably other buildings in the monastic range were renovated. The fragment is colourless, thin, flat and decorated with a Gothic letter 'm' that may have been part of a biblical inscription.

7.3 Bardney results

7.3.1 Stylistic results

There are 23 samples of glass from Bardney dated using the timeline of decorative motifs to the broad date ranges, late 12th, 14th, and 15th century. Twenty glasses are decorated and three are plain.

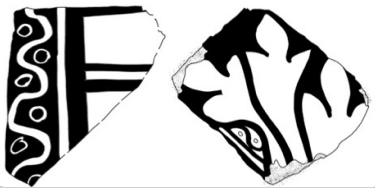
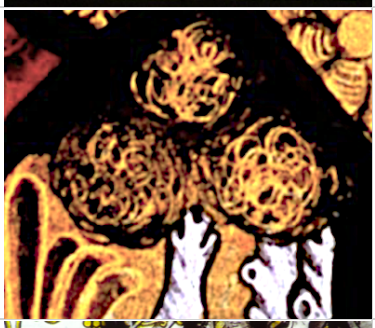
12th / 13th century

There is one 12th/ 13th century murrey coloured sample and although the decoration is unclear it is possibly a figural detail. Murrey glass was used up until the beginning of the 15th century for figural elements after which time uncoloured glass was used (Westlake, 1882, p. 2). The parallels from Canterbury Cathedral show a horse and hand detail and are dated to the late 12th and early 13th century (e.g. CVMA 3069).

14th century

There are eight samples that form one chronological group dated to the first half of the 14th century. Two samples are plain, of which one is coloured blue. The six remaining samples comprise five glasses with background diaper and border motifs, and a striated red fragment. This red fragment is decorated with a linear pattern that may have formed a narrow border or been used to edge a garment in a figural scene, for example the panel in the south window in the Chancel at Stanford on Avon, Northants, dated 1324-30 (e.g. CVMA 1552).

Several of the glasses can be compared with windows at Tewkesbury Abbey, 1338-40 (e.g. CVMA 1855, figure 7.10) and the east window in the Chancel at Eaton Bishop, dated around 1330-35 (e.g. 14741); BA5 and BA6 for example, are decorated with seaweed diaper in reserve (see glossary) and a serpentine border pattern. BA4 and BA13 are also serpentine patterns but are painted. The Tewkesbury Abbey window mentioned above is used to suggest an imagined scheme for the 14th century glasses from Bardney (Appendix 20a).

Figure 7.10 CVMA 1855 Tewkesbury		BA 5 & 6 
Figure 7.11 CVMA 20565, Coslany		BA 1
Figure 7.12 CMVA 14376, East Harling		BA 7 & 8

15th century

There are 14 samples that form one chronological group that dates to the mid to late 15th century. Three glasses are plain, one of which is coloured blue. The remaining decorated glasses comprise three coloured glasses, green, flashed red and blue that are decorated with diaper and border patterns (BA25 is indistinct), and eight naturally coloured glasses decorated with diaper and border decoration. There are also three glasses depicting what may be micro-architecture. Several glasses can be compared with panels from East Harling, 1465-80, for example BA7 and BA8 (CVMA 14376, figure 7.12). BA1 has a trefoil shape against an unusual background of squiggled lines that can be compared with a similar technique used to suggest foliage on a roundel from St Michael at Coslany in Norfolk, dated 1480 (CVMA 20565, figure 7.11). The similarities between much of the decoration at Bardney and the Norfolk dated parallels suggests that east coast glass painters working in their own local style may have been used for this glazing episode, see section 4.4.4. The main light panel from the east window at

East Harling (CVMA 14371) is used to suggest an imagined scheme for some of these 15th century glasses (Appendix 20b).

The summary table 7.5 shows that the glasses from Bardney Abbey represent three glazing episodes, from the late 12th/early 13th century, the second quartile of the 14th century and the mid to late 15th century.

Table 7.4 Bardney summary of dating using parallels

Date range	No. samples	Stylistic dating
C12/13	1	Late C12-early C13
C14	8	2nd Q C14, c. 1340
C15	14	Mid to late C15

7.3.2 Refined dating using EIDF for Bardney

Using EIDF, the dating of the glasses may be further refined by correlating with relevant building work and events at the abbey (figure 7.13).

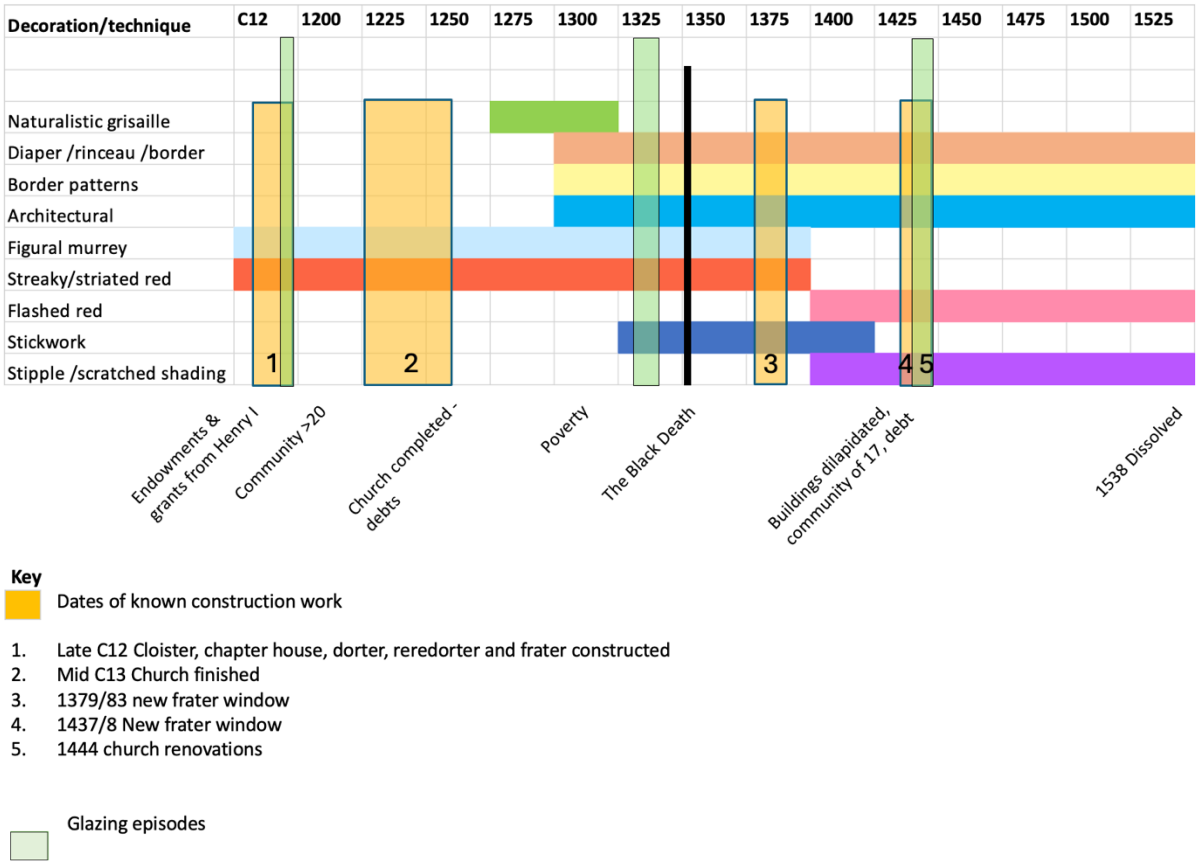


Figure 7.13 Bardney Evidence Informed Dating Framework

- The single murrey fragment may be refined to the late 12th century to correlate with the completion of the church.

- There are no glasses that correlate with the completion of the church in the mid-13th century. It is noted that there are aspects of later window designs in some of the decorative elements of the 14th century glasses. These include decoration such as foliage, beading and grisaille in windows from, for example, Oxford New College (c. 1380-86, e.g. CVMA 015034, 015025, 013036) and Winchester College (c.1393, e.g. CVMA 006842). The death of many glass painters due to the Black Death, added to the difficulty of importing glass from the continent may have interrupted the natural development of window design. For example, similar decorative schemes such as the figures within architectural canopies, examples of drolleries and grisaille quarries that were seen in the earlier 14th century continued to be used after the Black death albeit using a reduced range of colours and modelled (painted) in a stiffer manner (see examples above). However, on balance the evidence from the parallels suggests that these glasses were produced earlier in the 14th century, around 1330-40 and thus pre-date the Black Death. The dating of this glazing episode thus remains unchanged.

- It is possible that the mid to late 15th century glazing episode relates to a new window in the frater, dated around 1437/8 that Brakspear discusses (1922, p. 45).

The revised dating of the glasses from Bardney using EIDF is presented in table 7.6.

Table 7.5 Bardney Revised dating using EIDF

Date range	No. samples	Revised EIDF dating
C12	1	Late 12th century
C14	8	c. 1330
C15	14	c. 1437-38.

7.3.3 Technical results for Bardney

Every glass in the sample set from Bardney is heavily corroded with a weathered crust that in many of the samples obscures some of the decoration, but where the crust has flaked away the glassy core can be seen. Flaking is prevalent particularly around the edges, and as a result nearly half of the assemblage retains no original grozed edges and recognisable quarry shapes are few. There are two discernible shapes from the 14th century, a curved border piece and a square background quarry, and two from the 15th century, which are sub-triangular and

irregular shapes. Pitting is observed on two 14th century fragments, yet no lead shadows are evident to substantiate in-situ weathering. The poor surface conditions and small size of many fragments prevents an observation of bubble orientation and surface undulation to determine forming technique. Two fragments from the 15th century, however, have fire rounded edges demonstrating evidence of broad production. The 13th century glasses are thicker than the 15th century glasses, which is a trend in line with other groups of glasses in the project. There are coloured glasses in all date ranges: a 13th century murrey glass; 14th century blue and flashed red glasses; and 15th century blue, flashed red and green glasses. The naturally coloured glasses are very pale green to colourless.

7.3.4 Chemical compositional results for Bardney

The Bardney assemblage consists of 23 samples: the 12th and 14th century glasses are forest type and the 15th century glasses are HLLA. The discriminating elements, or variables, that best show the different groupings for Bardney are potassium, calcium, manganese, magnesium, sodium and silica.

The scatterplots of potassium oxide (K_2O) vs. calcium oxide (CaO) (figure 7.14) and potassium oxide vs. magnesium oxide (MgO) (figure 7.15) show that there are six compositional groupings: one in the 12th century date range, three in the 14th century date range and two in the 15th century date range.

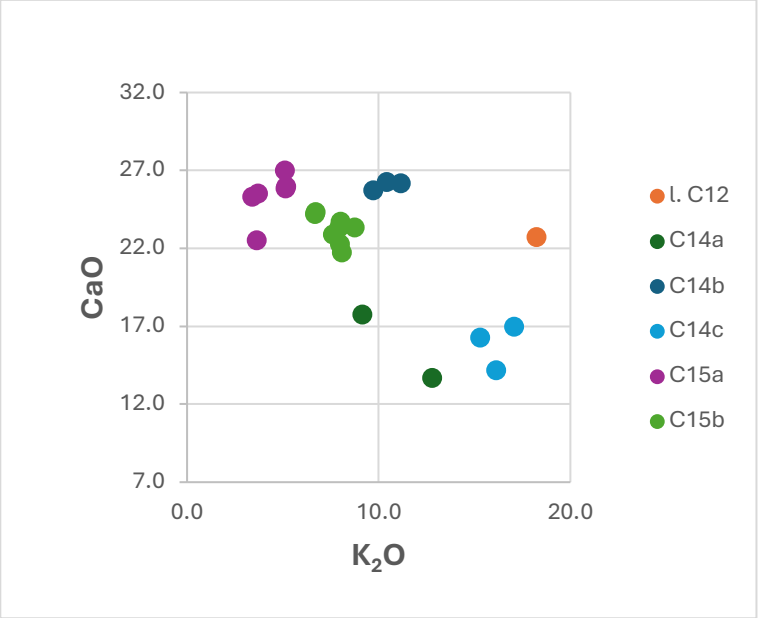


Figure 7.14 Bardney Scatterplot of potassium oxide vs. calcium oxide

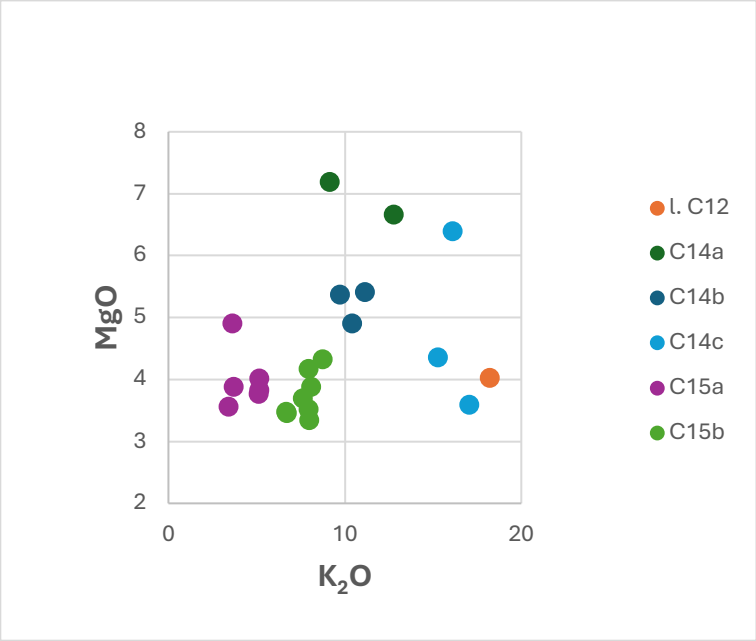


Figure 7.15 Bardney Scatterplot of potassium oxide vs. magnesium oxide

The PCA bi-plot for Bardney shows C14a and C14c close together in the fourth quadrant, along with the 12th century fragment (figures 7.16). C14c is more distinct. The two 15th century HLLA groups are shown in the first and second quadrant; reference to the vector shows the influence of calcium, manganese and aluminium on the PCs for the 15th century glasses (figure 7.17).

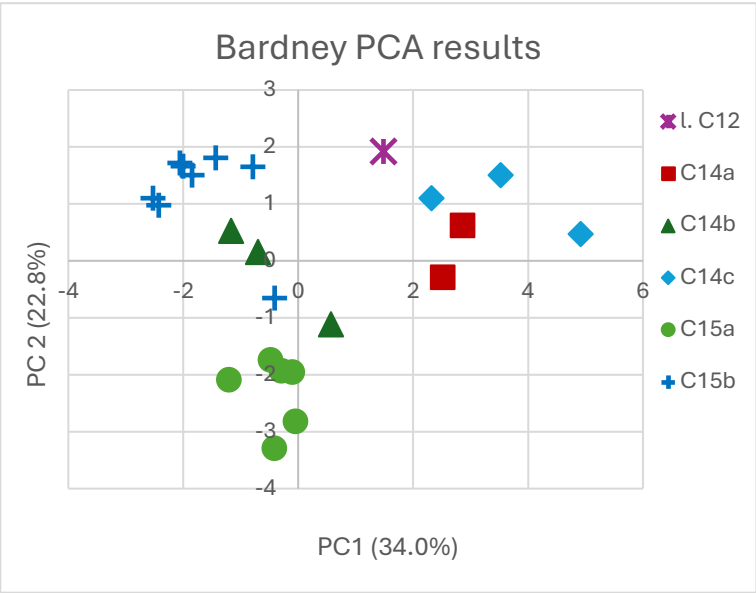


Figure 7.16 Bardney PCA Results

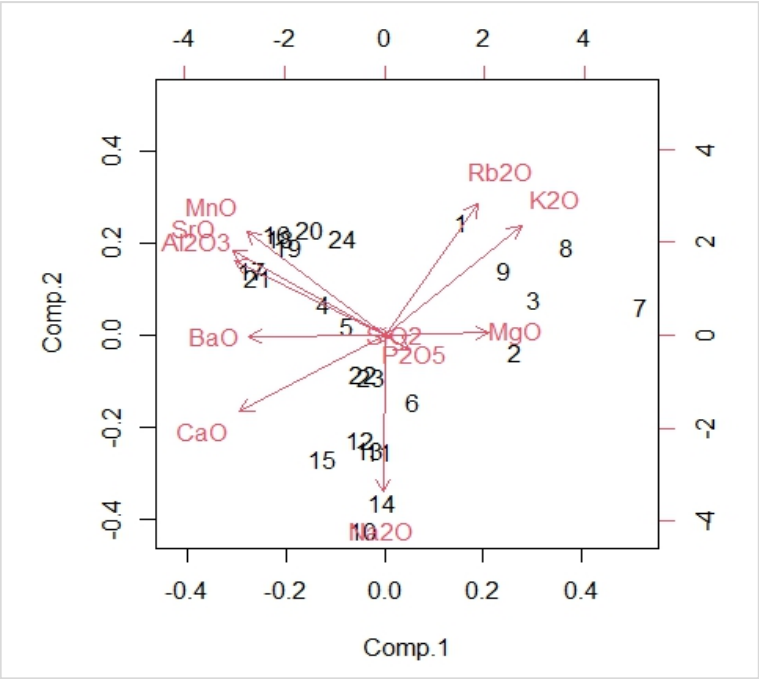


Figure 7.17 Bardney PCA vector graph showing loadings for PC1 and PC2

7.3.5 Compositional results for Bardney

The average amount of each discriminating element and standard deviations are shown in table 7.7.

Table 7.6 Average wt% of main discriminating oxides with standard deviation (SD) for Bardney. CS = no. of coloured samples

Group	No	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SrO	BaO	SiO_2	P_2O_5	CaO: K_2O	CS
C12	**1**	**18.25**	**1.35**	**n.d.**	**4.02**	**22.69**	**0.43**	**1.60**	**1.86**	**0.04**	**0.37**	**46.77**	**1.85**	**1.2**	**1**
C14a	**2**	**11.0**	**2.06**	**0.26**	**6.91**	**15.66**	**0.79**	**1.39**	**1.88**	**0.08**	**0.23**	**55.35**	**3.64**	**1.5**	**0**
SD		2.56	0.78	0.15	0.37	2.88	0.17	0.32	0.60	0.02	0.08	2.24	1.33	0.61	
C14b	**3**	**10.45**	**1.25**	**0.06**	**5.22**	**25.99**	**1.18**	**1.54**	**2.12**	**0.14**	**0.42**	**43.47**	**7.47**	**2.5**	**1**
SD		0.71	0.63	0.06	0.28	0.29	0.48	0.15	0.52	0.04	0.08	1.20	0.97	0.15	
C14c	**3**	**17.17**	**1.16**	**0.29**	**4.77**	**15.77**	**0.77**	**1.00**	**1.76**	**0.07**	**0.14**	**52.46**	**4.92**	**1.0**	**1**
SD		0.89	0.39	0.04	1.45	1.45	0.11	0.45	0.87	0.03	0.11	0.59	0.70	0.09	
C15a	**6**	**4.38**	**2.95**	**0.41**	**3.98**	**25.31**	**1.93**	**1.15**	**2.25**	**0.10**	**0.32**	**52.79**	**3.72**	**5.9**	**5**
SD		0.86	0.52	0.09	0.47	1.51	1.45	0.02	0.52	0.01	0.05	1.67	0.47	1.02	
C15b	**8**	**7.74**	**1.32**	**0.20**	**3.72**	**23.18**	**0.71**	**2.17**	**3.35**	**0.16**	**0.34**	**53.01**	**3.61**	**3.0**	**2**
SD		0.70	0.46	0.09	0.36	0.90	0.15	0.23	0.65	0.03	0.05	1.37	0.56	0.38	

Late 12th century

There is one fragment of late 12th century murrey coloured glass. As shown in table 7.7, it has a high level of potassium, calcium and manganese, and low amounts of silicon and phosphorus.

14th century

There are three compositional groups in this date range, all with a forest composition, C14a, b and c.

C14a

Table 7.7 shows that the two samples in C14a have high amounts of magnesium and sodium, and low amounts of potassium.

C14b

C14b comprises three samples characterised by high amounts of calcium, phosphorus and manganese, and low amounts of potassium and silicon (table 7.7). There is one blue coloured sample, BA 23, coloured with cobalt, see table 7.8 below.

C14c

As shown in table 7.7, C14c comprises three samples that are characterised by high potassium with an equal amount of calcium. The samples are similar to C14a but have lower levels of magnesium, manganese and sodium. One sample is coloured, BA2, (see table 7.8).

15th century

There are two 15th century groups, C15a and C15b, both HLLA compositions with low levels of potassium and high levels of calcium (in agreement with Adlington's formula, 2019, p. 57, (see section 2.3.5, chapter two)

C15a

As shown in table 7.7, C15a is characterised by low levels of potassium and high levels of calcium. There are high levels of iron, as well as sodium and chlorine, which correlate, suggesting the addition of salt (NaCl) to the melt (figure 7.18). An R-value for the slope of 0.912 suggests a strong linear correlation.

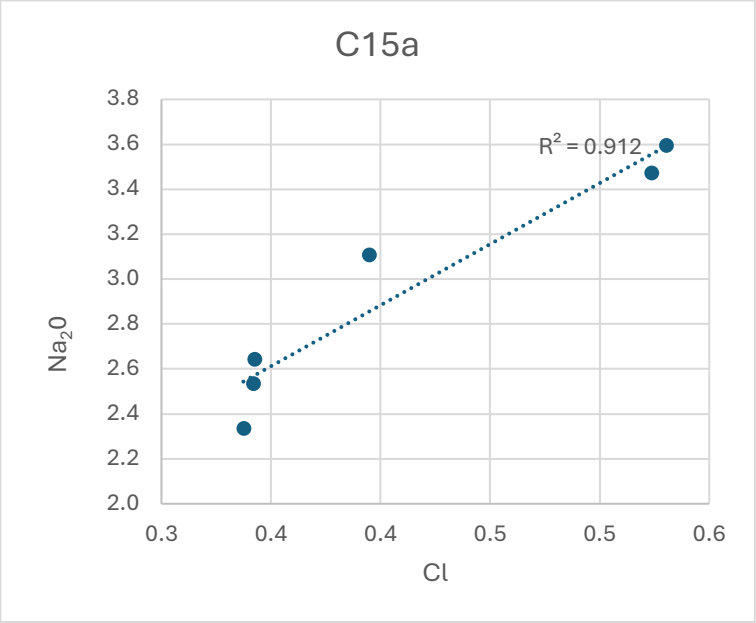


Figure 7.18 Bardney Correlation of chlorine vs. sodium suggesting addition of salt (NaCl)

C15b

Table 7.7 shows that these samples have an HLLA composition with a high level of calcium and manganese and a low level of potassium. Two samples (BA12, BA17) have elevated levels of aluminium that is possibly derived from contamination from the crucible.

7.3.6 Colour

The following table 7.8 shows how each of the intentionally coloured glasses from Bardney is coloured. The murrey colour was produced using a high amount of manganese in an oxidised state. The blue glasses are coloured with small amounts of cobalt, and the green and the flashed layer of the red glass are coloured with iron; the red glass in a reducing atmosphere and green glass in an oxidising atmosphere.

Table 7.7 Colourants and techniques used to manufacture the different coloured glasses at Bardney

Colour	Colourant	Samples	Date range	Information
Murrey	Coloured with MnO (1.60%) in an oxidised state	BA18	l. C12	Ratio of K:Si is high (0.39) as per Weyl (1951, p.129).
Striated red	Red not analysed	BA2	C14	Kunicki-Goldfinger type A (2014)
Flashed red	Fe_2O_3 (0.89%)	BA3		Reducing atmosphere Kunicki-Goldfinger type B (2014)
Blue	CoO (1.17%)	BA23	C14	
	CoO (0.18%; 0.19%; 0.02%)	BA7, BA8, BA24	C15	All three C15 blue glasses have a similar composition and may be from the same sheet, although the concentration of cobalt in BA24 is lower than in BA7 and BA8
Green	Fe_2O_3 (0.4.49%)			Oxidising atmosphere

7.3.7 Cullet

There is evidence for the introduction of cullet in the production of some of the glasses. Three non-coloured glasses, two from the 14th century (BA5, BA11) and one from the 15th century (BA19 have a trace amount of cobalt, and three non-coloured 14th century samples have trace amounts of copper (BA5, BA6, BA22) showing that coloured cullet was used in the batch.

7.3.8 Summary of analytical results for Bardney

There are three glazing episodes represented by 23 fragments that date from the late 12th to the 15th century. The late 12th century glazing episode is represented by a single fragment of high-calcium forest glass that ties in with the completion of the claustral range. It is moderately thick, murrey coloured and appears to be decorated with a figural motif. It may be from a specialist producer of murrey coloured glass.

The second glazing episode is represented by eight forest glasses. The glasses are dated using parallels to around 1330, but it is noted that aspects of the decoration are also seen on glasses that date to the second half of the 14th century, after the Black Death. The glasses in the three compositional groups range in thickness (C14c is thickest and C14b is thinnest) and all of the non-coloured glasses are similarly pale green. The glazing scheme represented by the glasses

may have been figural with grisaille and foliate motifs. There is compositional evidence of the addition of coloured cullet in some of the 14th century glasses.

The third glazing episode is dated to around 1437/8 to a glazing episode in the frater. The two compositional groups are similar except for C15a may have added salt (NaCl) and C15b is high in manganese and may have been intentionally decoloured. Both groups of glasses have a refined quality and were probably part of a figural window scheme.

7.4 Bordesley

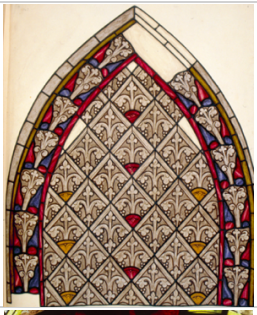
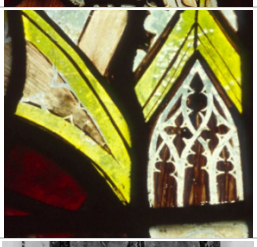
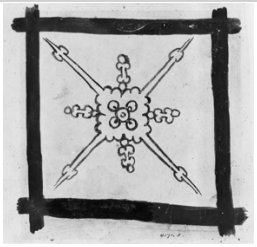
7.4.1 Stylistic results

There are 40 samples of glass from Bordesley dated using the timeline of decorative patterns and motifs to the broad date ranges, 13th, 14th and 15th centuries. Thirty-six glasses are decorated, three are plain and there is one bull's eye. Examples of dated parallels for each sample of decorated glass are presented in tables (Appendix 51).

13th century

There are nine samples that form two chronological groups: C13a is dated to the early 13th century and comprises seven decorated fragments, C13b is dated to the late 13th century and comprises two coloured fragments, a decorated green glass and a plain blue glass.

In the C13a sub-group there are three fragments with open beading (B5, B17, B18) and four fragments decorated with stiff leaf grisaille motifs of trefoil heads on a cross-hatched ground (B1, B2, B7, B8). B2 is a fragment from a larger, diamond-shaped quarry that shows a fruiting trefoil with one berry. Similar diamond grisaille quarries are found at Westwell, which is dated to the early 13th century and has three berries (CVMA 7386, figure 7.19); Lincoln, also dated early 13th century that has no berries (CVMA 7408), and Stodmarsh, which is dated to the late 12th century and has six berries (CVMA 5856). B8 is also fruiting with one surviving berry close to the broken edge, but two are shown on the Ellen Walsh and Lesley Collett illustrations, demonstrating some post-excavation deterioration. The two remaining grisaille motifs are paralleled with Lincoln and Salisbury cathedrals and are dated early to mid-13th century (e.g. CVMA 210 and CVMA 9954). The three glasses decorated with open beading have a wider date range from the 12th to the 14th century but parallels from the first half of the 13th century include Canterbury Cathedral dated 1213-20 (CVMA 2934). The decorated green glass in C13b is a late 13th century semi-circular quarry with foliate decoration on a plain ground. Dated parallels are from Stanton Harcourt, dated 1260-75 (CVMA 3312) and Chartham St Mary, dated 1294 (CVMA 5472).

Figure 7.19 CVMA 7386, Westwell		B8
Figure 7.20 CVMA 14741, Eaton Bishop		B28
Figure 7.21 CVMA 14741, Eaton Bishop		B30
Figure 7.22 CVMA 10006, Merton college. Drawing by O Hudson, V and A (4163.27)		B24 & 47
Figure 7.23 CVMA 18157, St Martin-le-Grand		B48
Figure 7.24 CVMA 25569, Clavering		B26
Figure 7.25 CVMA 10153, Waterperry. Drawing by O Hudson, V and A (4171.8)		B45

14th century

There are 24 fragments that form one chronological group that dates to the early to mid-14th century. Twenty of the glasses are decorated and four are plain, one of which is a striated red glass (B40) (although catalogued by BA Project as flashed red). B42 is a bull's eye. The decorated glasses include six coloured amber, yellow and blue (B37, B38, B44, B28, B23, B35).

Nearly half of the decoration is of naturalistic grisaille, background diaper, foliate motifs and heraldic imagery plus there are five fragments depicting micro-architecture (B29, B37, B38, B30, B35) and one fragment painted with drapery folds (B28). These motifs are typical of 14th century window decoration with a figure such as a saint placed under an image of an architectural canopy, with background diaper and border patterns. Windows of this type are found at Eaton Bishop Church, Hereford, 1330-35 (e.g. CVMA 14741, figure 7.20 and 7.21), Tewkesbury Abbey, dated 1338-40 (e.g. CVMA 1761), and Merton College dated to around 1310, where heraldic devices such as fleur de Lys are used (CVMA 10006, figure 7.22). Another panel from the same window at Merton College (CVMA 4113) is used to suggest an imagined scheme for the 14th century glasses from Bordesley (Appendix 21). There are two fragments with foliage that have cross-hatched stems (B1, B11). Illustrations of similar foliage are included in Woodward's (1866) report of his investigations at Bordesley Abbey (see section 5.5.3).

15th century

There are seven fragments in one chronological group that dates to the first half of the 15th century. All glasses are decorated, and one is silver-stained (B39). Decoration includes seaweed diaper, and around a half of the group comprises images of micro-architecture (B31, B32, B48, B39) with parallels from St Martin-le-Grand (e.g. CVMA 18157, figure 7.23), Great Malvern Priory (e.g. CVMA 9029) and Waterperry (CVMA 10153, figure 7.24). B26 depicts angel feathers with a parallel from Clavering dated to around 1450 (CVMA 25569, figure 7.25).

Table 7.9 shows that the glasses in the assemblage from Bordesley Abbey represent four glazing episodes, the early and late 13th century, the early to mid-14th century and the first half of the 15th century.

Table 7.8 Bordesley, summary of dating using parallels

Date range	No. samples	Stylistic dating
C13a	7	Early C13
C13b	2	Late C13
C14	24	Early to mid-C14
C15	7	First half C15

7.4.2 Refined dating using EIDF for Bordesley

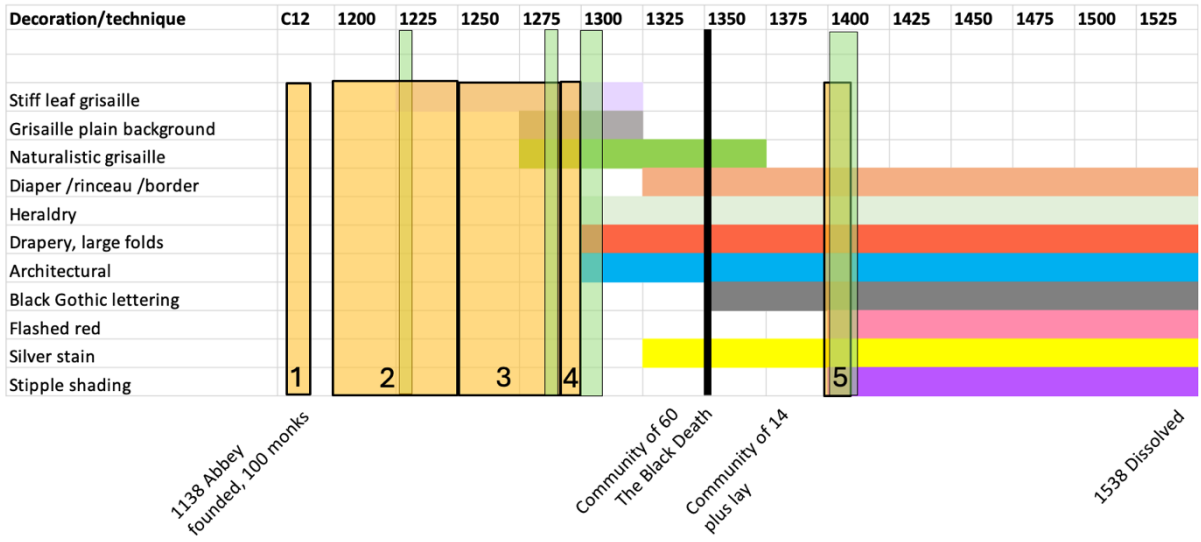
Using EIDF, figure 7.26, the dating of the glasses may be further refined by correlating with relevant building work at the abbey.

- Between 1200 and 1250, parts of the east end of the church and choir were rebuilt and a new stone night stair constructed. The early 13th century glasses correlate with this building phase, however the dating using the parallels to the early 13th century cannot be improved on thus the dating remains unchanged.

- The dating of the late 13th century glasses also remains unchanged as, although renovations to the church tower and crossing were undertaken in the second half of the 13th century the dating from the parallels cannot be improved on.

- The date of the rebuilding of the gatehouse chapel is the late 13th and into the 14th century (Hirst, Walsh and Wright, 1983, p. 43, 54; Astill, Hirst and Wright, 2004, p. 113). The glasses retrieved from this location (as well as glasses of a similar composition retrieved from other locations around the abbey site) are dated by parallels to the early to mid-14th century. The glazing of the building would have followed soon after the construction work was completed, therefore it may be possible to revise the date of the glass to the earlier part of the 14th century. This is the same dating as Merton College chapel, which was constructed in the late 13th century but glazed around 1310 (e.g. CVMA 6058) (Ayres, 2013).

- There are five 15th century glasses from the church (dated by the parallels to the first half of the 15th century) that may be linked to the rebuilding programme dated to around 1400. There is also a glass of the same composition retrieved from the gatehouse chapel, and which is probably a replacement glass (see section 4.2.1).



Key

Dates of known construction work

1. 1150-60 Church completed
2. 1200-50 Parts of east end and choir rebuilt; new stone night stair
3. C13 2nd half Church crossing rebuilt, tower raised
4. Late C13 gateway chapel rebuilt
5. C. 1400 Contraction of claustral range

Glazing episodes

Figure 7.26 Bordesley Evidence Informed Dating Framework

The revised EIDF dating of the Bordesley glasses are shown in table 7.10

Table 7.9 Bordesley Glasses new revised dating using EIDF

Date range	No. samples	Stylistic dating
C13a	7	Early C13
C13b	2	Late C13
C14	24	Early C14
C15	7	c. 1400

7.4.3 Technical results for Bordesley

All fragments from the assemblage are severely weathered, which necessitated the mounting of four samples in resin blocks (B46, B47, B45, B48). This was to expose the glassy core for chemical analysis since there was no glass visible for a surface analysis. Five samples were also consolidated with polyvinyl acetate glue (PVA) prior to the research described here (B12, B43, B14, B45, B19). Evidence of in-situ weathering is seen in all date ranges but is prevalent in the 14th century groups where one third of the glasses has pitting on the external surface (e.g. B19). Nonetheless, two thirds of the fragments retain at least one grozed edge and 10 original quarry shapes are identified. In the 14th century groups original shapes are particularly diverse and comprise triangle/diamond (B12, B44, B10) sub-triangle (B15), sub-rectangle (B19), rectangle (B35) and freehand (B24). In contrast, colours across all date ranges are fairly reserved with blue and amber in the 13th century and blue, amber and striated red in the 14th century. There are no coloured fragments in the 15th century group although one fragment depicting possible micro-architecture is silver-stained (B39). Naturally tinted glasses are all pale green, and it is of note that there are no completely colourless glasses in this group of glasses (all non-coloured glasses are tinted pale green).

The average thickness of the glass dated between the 13th and 15th century, is progressively thinner, although it is by only a marginal amount, 3.6 to 2.9 mm. Thus, the 15th century glasses are relatively thick and tinted compared with other 15th century glasses from the study, for example glasses from Alcester and Hyde that are thin and colourless. Some of the 13th century glasses contain inclusions of un-melted batch. There is evidence of crown production in group C14b based on a tapering thickness (B41, B43), which is corroborated by the bull's eye off-cut in the same compositional group. The presence of the bull's eye in the assemblage (B42) is intriguing as it shows no evidence of having been used in glazing and is thus similar to H102. Although bubbles are observed in a linear orientation in a 13th century and a 15th century sample (B2, B32), the area is too small to assign broad production. All painted decoration is a red-brown colour.

7.4.4 Chemical compositional results for Bordesley

There are five groups of glasses dated from the 13th to the 15th century. All of the glasses have a forest composition and the discriminating elements, or variables used to show the groupings for Bordesley are potassium, calcium and magnesium

The scatterplots of potassium oxide (K_2O) vs. calcium oxide (CaO) (figure 7.27), potassium oxide vs. magnesium oxide (MgO) (figure 7.29) and magnesium oxide vs. calcium oxide (figure 7.31) show a complex picture with overlapping groupings across date ranges. Compositional groupings are more obvious where the date ranges are separated out. This is shown in the following scatterplots: figure 7.28 shows well-defined 13th and 15th century groupings for potassium vs. calcium; figure 7.30 shows the 14th century ratios for potassium vs. magnesium

with only two points overlapping but otherwise as clear groups, and figure 7.32 shows the same 14th century groups well defined except for a small area of overlapping. While the groups from each date range are shown to be fairly discrete, there are clearly overlapping compositions across the date ranges.

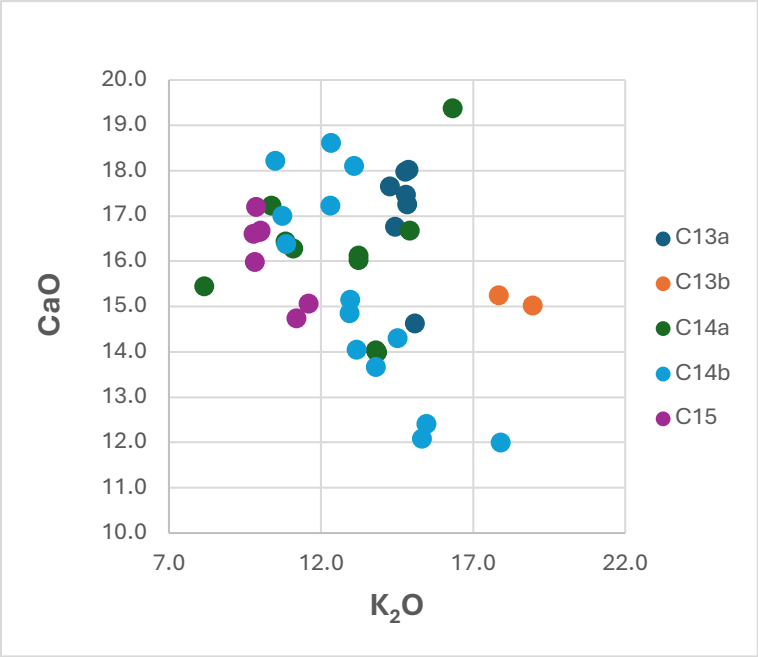


Figure 7.27 Bordesley scatterplots of potassium oxide vs. calcium oxide

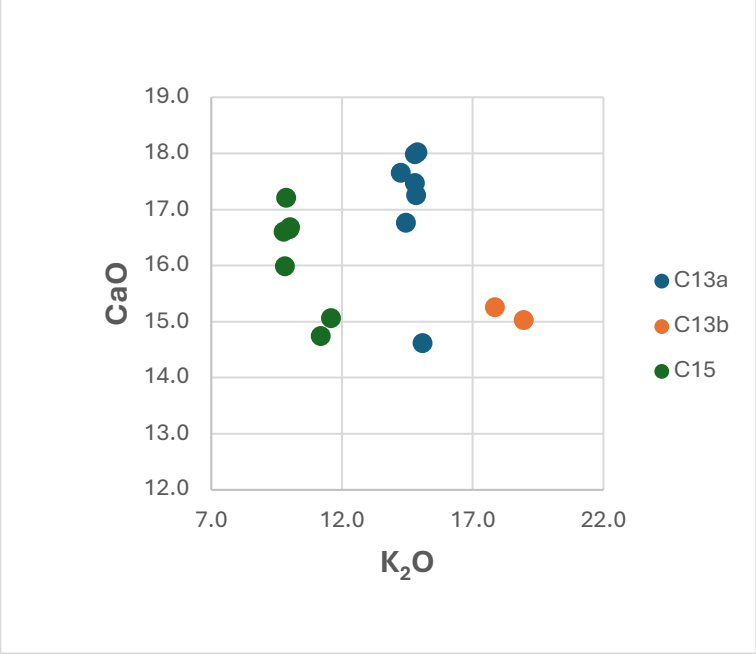


Figure 7.28 Bordesley scatterplots of potassium oxide vs. calcium oxide

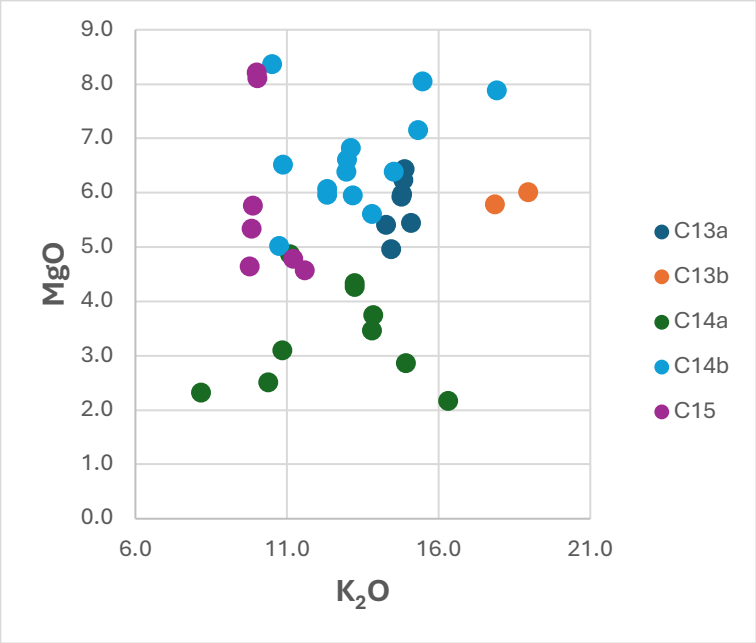


Figure 7.29 Bordesley scatterplots of potassium oxide vs. magnesium oxide

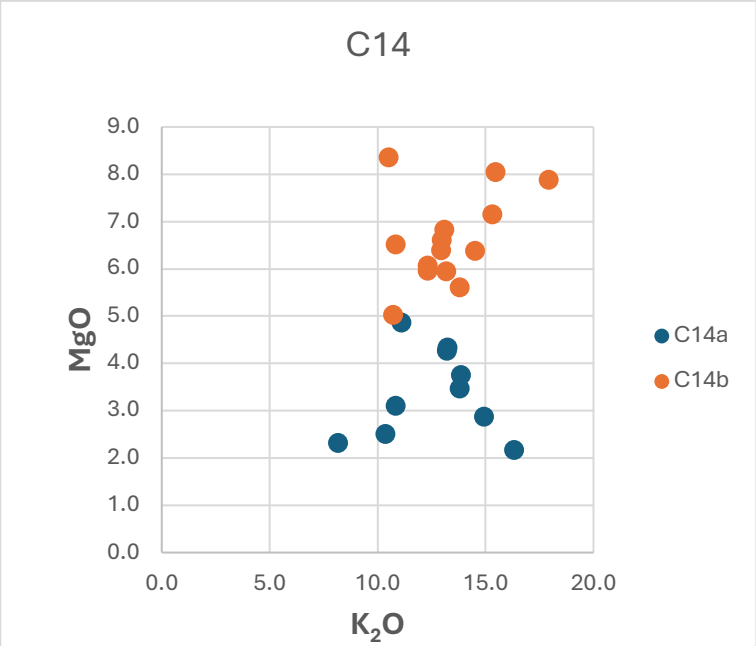


Figure 7.30 Bordesley scatterplots of potassium oxide vs. magnesium oxide

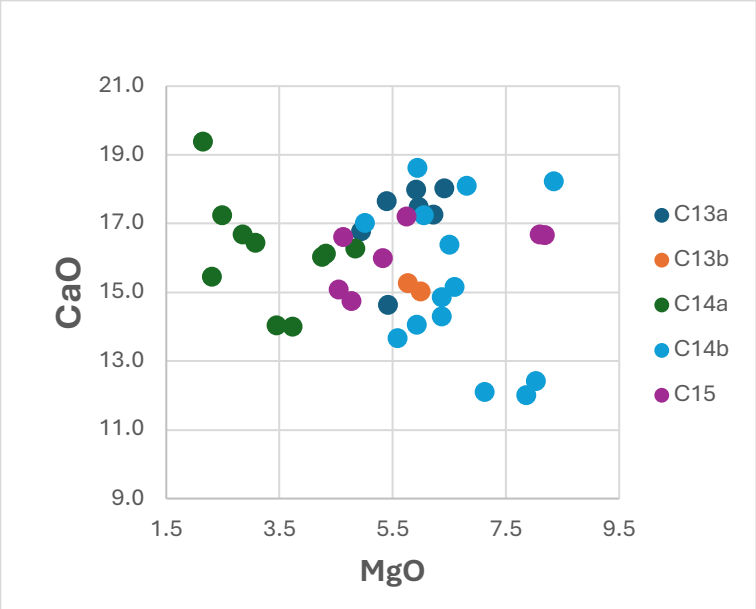


Figure 7.31 Bordesley scatterplots of magnesium oxide vs. calcium oxide

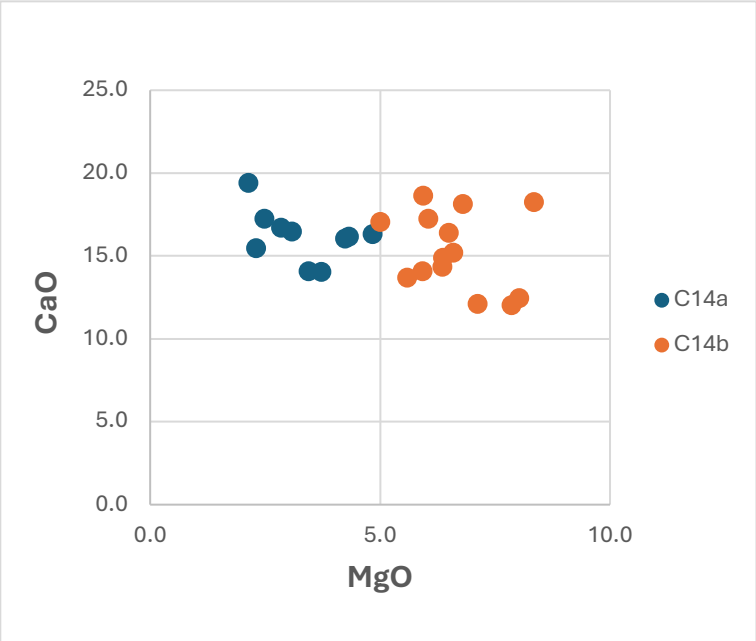


Figure 7.32 Bordesley scatterplots of magnesium oxide calcium oxide

7.4.5 Compositional points from the chemical analysis of the Bordesley glasses

The main compositional points for the groupings from all date ranges are presented (table 7.11).

Table 7.10 Average wt% of main discriminating oxides with standard deviation (SD) for Bordesley. CS = no. of coloured samples

Group	No.	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SiO_2	P_2O_5	CaO:K_2O	CS
C13a	**7**	**14.74**	**1.13**	**0.30**	**5.76**	**17.10**	**0.92**	**1.36**	**1.85**	**50.34**	**5.71**	**1.2**	**0**
SD		0.28	0.19	0.04	0.52	1.18	0.07	0.06	0.20	1.82	0.71	0.09	
C13b	**2**	**18.42**	**1.70**	**0.23**	**5.89**	**15.13**	**1.12**	**1.09**	**1.95**	**46.65**	**5.42**	**0.8**	**2**
SD		0.78	0.10	0.02	0.16	0.16	0.55	0.09	0.24	1.88	1.28	0.04	
C14a	**10**	**12.60**	**1.10**	**0.34**	**3.35**	**16.15**	**0.89**	**1.44**	**2.22**	**55.35**	**5.88**	**1.3**	**3**
SD		2.43	0.26	0.08	0.93	1.55	0.21	0.43	0.46	2.09	2.25	0.29	
C14b	**14**	**13.30**	**2.30**	**0.38**	**6.61**	**15.28**	**0.70**	**1.34**	**1.60**	**53.30**	**4.27**	**1.2**	**4**
SD		2.05	0.63	0.06	0.96	2.32	0.20	0.32	0.43	2.39	0.83	0.33	
C15	**7**	**10.34**	**1.21**	**0.24**	**5.91**	**16.12**	**0.55**	**1.67**	**1.37**	**58.75**	**3.26**	**1.6**	**0**
SD		0.74	0.17	0.02	1.59	0.31	0.08	0.14	0.34	1.76	0.66	0.18	

C13

There are two 13th century groups, C13a and C13b:

C13a

As shown in table 7.11, C13a is characterised by high amounts of magnesium, phosphorus and calcium. There are no coloured glasses.

C13b

Table 7.11 shows that C13b is a group of two samples both coloured, blue and amber (see table 7.12 below) with a composition that is characterised by low silica, and high magnesium, phosphorus and potassium.

14th century

This date range consists of two compositional groups, C14a and C14b:

C14a

C14a is a group of 10 samples with high amounts of manganese and phosphorus, low amounts of magnesium and a Ca:K ratio of 1.3 (table 7.11). The three coloured samples that are amber, B37, B38 and B44, have very similar compositions and may be from the same sheet (see table 7.12 for colourants).

C14b

C14b is characterised by high levels of potassium, magnesium, manganese and sodium, with a Ca:K ratio of 1.2 (table 7.11). Two plain glasses (B41, B43) are probably from the same sheet of glass as their compositions are very similar. There are four coloured samples, one each of

amber and flashed red, and two blue glasses. The colourants used in these samples are recorded below (table 7.12). The group includes a bull's eye.

15th century

There is one compositional group in this date range that is characterised by high magnesium, manganese and silica, and low potassium and iron (table 7.11). The seven samples are compositionally close, and some of the glasses are so similar that they are probably from the same glass sheets (B21 and B31; B32 and B39; and B45 and B48). There are no coloured samples in this date range.

7.4.6 Coloured glasses

The following table 7.12 shows how each of the intentionally coloured glasses from Bordesley is coloured. The blue glasses are coloured with trace amounts of cobalt and because there are also small quantities of copper, zinc and lead it is probable that brass filings, together with a cobalt source were added to the batch (Gratuze, Pactat and Schibille, 2018). The green glasses have copper and lead suggesting the addition of some form of copper alloy, possibly copper scrap metal.

The three amber glasses are coloured in a reducing furnace atmosphere with a high level of potassium to enable the glass to melt at a lower temperature (13.44% compared with the average level in the rest of the group of 11.55%). The colouration of amber glass may also be dependent on the amount of carbon present (Paynter and Jackson, 2018, p. 569) however, this is not measured in this study. The yellow glass is coloured with copper (1.59%) and lead (0.30%). The striated red glass is coloured with copper (0.86%).

Table 7.11 Table showing how each intentionally coloured glass from Bordesley is coloured

Colour	Colourant	Samples	Date range	Information
Blue	CoO (0.11%)	B36	C13b	Cu, Zn, Pb indicates the possible addition of a Cu alloy such as brass (B. Gratuze, Pactat and Schibille, 2018)
	CoO (0.08%)	B28	C14b	
	CoO (0.9%)	B35		
Green	CuO (2.12%), reducing furnace atmosphere	B46	C13b	Zn, Pb also present
Amber	Reducing atmosphere, possibly carbon added	B37, B38, B44	C14a	(Paynter and Jackson, 2018, p. 569)
Amber/ yellow	CuO (1.59%)	B23	C14b	Pb (0.30%) also present
Striated red	CuO (0.86%) in a reducing furnace atmosphere	B40		Kunicki et al. (2014) type A

7.4.7 Cullet

There is evidence in the Bordesley glasses of the use of coloured cullet in the production of some of the non-coloured glasses as demonstrated by the presence of trace amounts of cobalt and lead. These are two samples in C13a (B5, B6) and one sample in C14a (B12). There are no colourants in the compositions of the 15th century non-coloured glasses.

7.4.8 Summary of the results for Bordesley

All of the glasses are a forest glass composition and represent four glazing episodes, the early 13th, late 13th and early 14th century, and around 1400. Three of the episodes can be tied to the building and renovations of the church and other key buildings in the complex. The severely weathered condition of many of the glasses results in difficulty determining the forming technique in the majority of the glasses although a tapering profile of some of the glasses shows crown production.

The first glazing episode comprising seven glasses is dated using parallels to the early 13th century. The fragments are naturally coloured pale green, relatively thick, contain inclusions of un-melted batch and there is compositional evidence of the use of coloured cullet in production. The glasses were part of a stiff leaf grisaille scheme of decoration.

The second episode is dated using parallels to the late 13th century yet may tie in with renovations to the church in the second half of the 13th century. The two fragments from this episode are both thick and coloured, blue and green and would have belonged to a grisaille window scheme. There is compositional evidence for the use of coloured cullet in the production.

The episode linked with the rebuilding of the gatehouse chapel and glazing in the church is dated to the early 14th century and there are 24 glasses comprising four compositional groups. One group contains a bull's eye and other glasses of the same composition are crown-produced. The range of colours and motifs show that the glasses were probably part of figural windows with heraldic devices in the borders.

The fourth glazing episode comprises seven glasses dated to around 1400 when parts of the church were rebuilt. They are all naturally coloured and moderately thick and were possibly part of a figural or heraldic scheme of decoration, using silver-stain for highlights of colour.

7.5 Hyde

7.5.1 Stylistic results

There are 48 samples of glass from Hyde dated using the timeline of decorative motifs to broad date ranges, the 13th, 14th and 15th century. Forty-two glasses are decorated, five are plain and there is one bull's eye

12th century

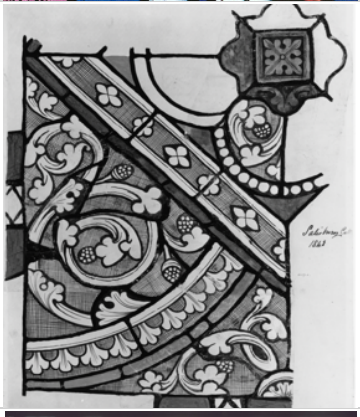
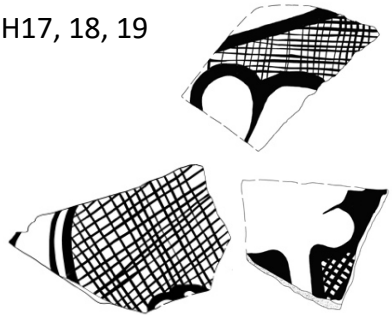
Sample H41 is a single glass depicting drapery, possibly the folds of a sleeve and it is dated to the late 12th century. The parallels are from Canterbury Cathedral (Michael, p. 61, 90, 96, figure 7.33) and York Minster (CVMA 4588), both of which are dated to the late 12th century and exhibit a similarly thick outline to the garments depicted and linear folds.

13th century

There are four 13th century samples all of which are decorated with stiff leaf grisaille motifs, of foliate heads, strapwork and a cross-hatched ground. The parallels are from Lincoln (e.g. CVMA 7434) and Salisbury Cathedrals (e.g. CVMA 9954, figure 7.34), both dated to the early to mid-13th century.

14th century

There are 13, 14th century samples from one chronological group. All are naturally coloured, eight are decorated and five are plain. The decorated samples include Gothic lettering (H52), naturalistic grisaille (H65) and vegetal motifs (H32), also border patterns (H85), and two samples that may be strapwork or perhaps architectural (H14, H87). Five of the samples are silver-stained (H14, H56, H65, H85, H87). The motifs in the whole group are varied and there are a number of parallels that include Eaton Bishop, dated 1330-35 (e.g. CVMA 2908), Kingerby, dated 1345-50 (e.g. CVMA 2065) and York Minster dating to the early 14th century (e.g. CVMA 3689). There are no figural motifs or coloured fragments in the group, and the glasses may have been part of a grisaille scheme not unlike the east window in the chancel at All Saints in York, dated to around 1335-50 (CVMA 5336, figure 7.36). Here, a large part of the panel is made up of individual quarries decorated with naturalistic grisaille and vegetal motifs with silver stained strapwork borders.

Figure 7.33 Michael, 2019, p. 90, Canterbury Cathedral		H41
Figure 7.34 CVMA 9954, Salisbury Cathedral		H17, 18, 19 
Figure 7.35 CVMA 5336, All Saints, York		H31, 65
Figure 7.36 CVMA 25242, Margaretting		H54

15th century

There are 30 fragments that form one chronological-group that dates to the mid-15th century. The group comprises 29 decorated glasses, seven of which are coloured, red and blue, and 11 that are silver stained. There is one plain bull's eye. Decoration includes three glasses with Gothic lettering (H53, H89, H54), around a third of the group with seaweed diaper and background foliate motifs (e.g. H9) and another third with depictions of micro architecture that includes masonry highlighted in silver stain and black and white tessellated flooring (e.g. H91). There are also rosettes (e.g. H70) that may have been part of a border pattern or been

used to edge a garment, for example as seen at Clavering, dated to around 1450 (CVMA 25565). The glasses were probably part of a figural scene with a figure set within an architectural canopy. It is unclear what the Gothic lettering constitutes but it may have comprised biblical passages or names of donors. H54 is more embellished than the other Gothic letters in the group and has parallels at Margaretting, dated to the mid-15th century (e.g. CVMA 25242, figure 7.36), Clavering (CVMA 25565) and All Saints, York, dated to around 1412-28 (CVMA 5237). Other dated parallels for the decorated glasses include Wrangle, dated 1410-30 (CVMA 23303), Great Malvern Priory, dated to the mid-15th century (e.g. CVMA 10169) and St Martin-le-Grand, dated to around 1442 (e.g. CVMA 18173). The Wrangle parallel has similar background diaper decoration, Gothic lettering and architectural features, including the tessellated flooring. This window is used to suggest an imagined scheme for the 15th century glasses from Hyde (Appendix 22).

The summary table 7.13 shows that the Hyde glasses, dated by way of the dated parallels, represent four glazing episodes, the late 12th, early to mid-13th, mid-14th and the mid-15th centuries.

Table 7.12 Hyde, summary of dating using parallels

Date range	No. samples	Stylistic dating
C12	1	Late C12
C13	4	Early-mid C13
C14	13	Mid-C14
C15	30	Mid-C15

7.5.2 Refined dating using EIDF for Hyde

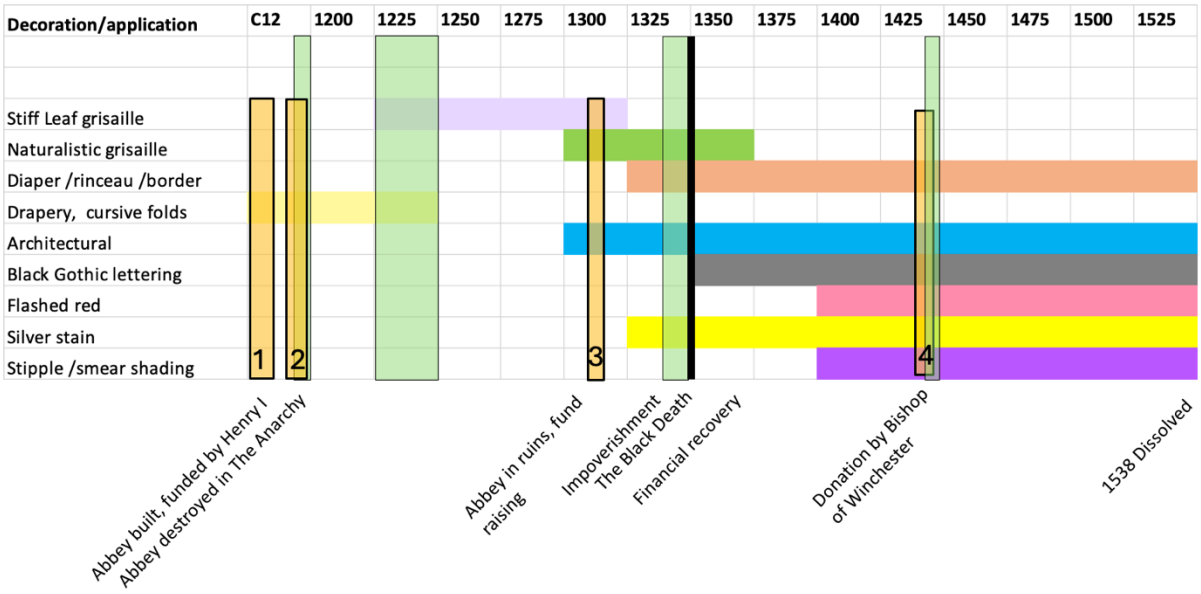
Using EIDF, figure 7.37, the dating of the glasses may be further refined by correlating with relevant building work at the abbey. The find-spot of the glasses is thought to be the abbot's lodgings and although there is no documented evidence of glazing relating specifically to this building, evidence from other sites (for example, Bordesley) shows that glazing was installed across multiple buildings as part of the same glazing commission. Evidence of schemes of work elsewhere in the complex may therefore be relevant to glazing at the abbot's lodgings.

- The late 12th century glass can be associated with the reconstruction of the abbey buildings around 1182 after they were destroyed during the Anarchy, thus corroborating the date identified using the parallels

- The early to mid-13th century glasses may also be a later part of this programme of reconstruction although the dating cannot be further refined, and the dating remains unchanged

- The repair work to the parts of the monastery in 1312 may be linked to the 14th century glasses, however the TPQ of the Gothic lettering on H52 is currently dated to around 1340-50 (Marks, 1993, p. 167) therefore this glazing episode cannot be linked with any known building work at the abbey and thus the glasses remain dated by the parallels. However, it is highly likely that this glazing episode predates the Black Death, thus a revised dating of around 1340 is suggested

- There are known repairs to the church after a fire around 1446. Since this date is very close to the one accorded by the parallels it seems probable that new glazing was installed at the abbot's lodgings at the same time



Key

Dates of known construction work

1. 1110 Abbey built
2. 1182 Abbey rebuilt after destruction
3. 1312 repairs
4. 1446 Bell tower and other parts of complex rebuilt

Glazing episodes

Figure 7.37 Hyde, Evidence Informed Dating Framework

The revised dating of the glasses from Hyde using EIDF is presented in table 7.14

Table 7.13 Revised dating using EIDF

Date range	No. samples	Revised dating with EIDF
C12	1	Late C12
C13	4	Early-mid C13
C14	13	Mid C14
C15	30	c. 1446

7.5.3 Summary of technical results for Hyde

This is a large sample set of 48 glasses forming 10 compositional groups. The group contains one of the two oldest samples in the project, a late 12th century blue glass (H41). All of the 13th century glasses are weathered, some severely, and all are pitted on the exterior showing that they were corroded while installed. The condition of the 14th century glasses is less severe although many are pitted and the vast majority of the 15th century groups are in good, uncorroded condition. Groups C15a and C15b however, contain three samples with pitting, demonstrating weathering in-situ of the glasses H53, H89 and H54.

There are eight coloured glasses in the assemblage: these are the single 12th century sample and all seven glasses from C15c. There are only two colours present in the sample set, blue and flashed red. All of the naturally coloured glasses up to and including C15b are pale green. C15d and C15e glasses are distinguished by their finesse, being colourless and of a consistent thinness that suggests broad production. Seven of the 15th century glasses have indents on the exterior sides from sand on the furnace floor during the flattening process, showing that they are broad glasses. H32 and H85 from the large 14th century group have evidence of crown production by way of tapering profiles. H32, which is the thickest glass in the study (other than the bull's eyes) measures 7 mm at one end and 5 mm at the other. On average, the glasses reduce in thickness from 4.0 mm to 2.4 mm over the course of the 13th to the 15th century. Of interest is the crown glass bull's eye, which like B42 is roughly cut out and shows no evidence of having been glazed. Approximately half of the assemblage retains at least one grozed edge although there are only three original quarry shapes, all of which are in the 14th century group and are either a background or a border quarry (H32, H255, H85).

7.5.4 Chemical compositional groupings for Hyde

Fifteen glasses from the 13th, 14th and 15th century have a forest glass composition, 22 of the 15th century glasses are HLLA and there is one 12th century soda glass. The discriminating elements that best show the different groupings for Hyde are potassium, calcium, magnesium and manganese.

The scatterplots of potassium oxide vs. calcium oxide (CaO) (fig 7.41) and potassium oxide (K_2O) vs. magnesium oxide (MgO) (fig 7.42) show that there are up to eight compositional groupings, one in each of the 12th, 13th and 14th centuries, and five groups in the 15th century. The groupings represent four glazing episodes at the abbey. There is, however, overlap in the concentrations that demonstrates that some of the groups are compositionally similar over more than one date range.

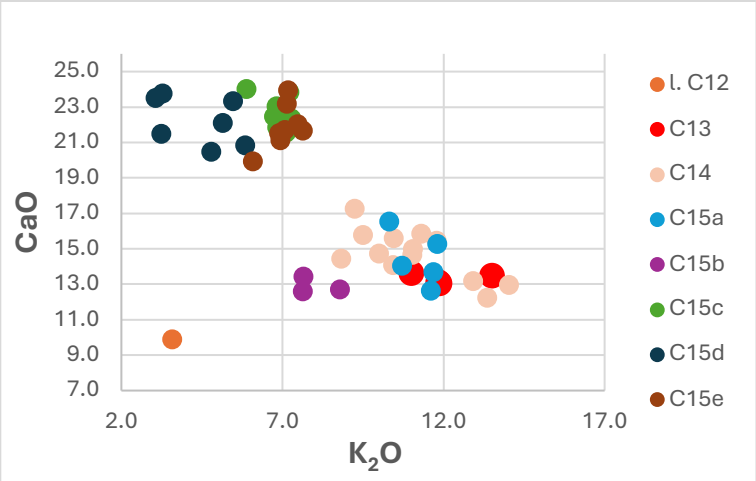


Figure 7.38 Hyde Scatterplots of potassium oxide vs. calcium oxide

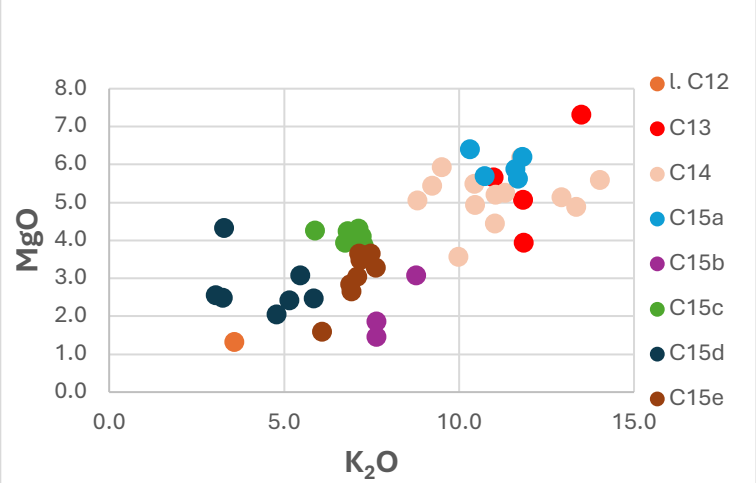


Figure 7.39 Hyde Scatterplots of potassium oxide vs. magnesium oxide

Two clusters can be distinguished in figure 7.38 (excluding the single 12th century soda glass), one cluster containing the 13th, 14th and C15a forest glasses with lower calcium levels, and a second cluster containing the 15th century HLLA groups with high levels of calcium and low potassium. The 12th century glass is distinguished by low levels of potassium and calcium in figure 7.38, and low magnesium in figure 7.39. In the PCA bi-plot the forest glass compositions are shown in the third and fourth quartiles and the HLLA glasses are shown in the first and second quartiles (figure 7.40). The vector graph shows the influence of calcium on the PCs of the 15th century HLLA glasses and the influence of magnesium on the forest glasses (figure 7.41).

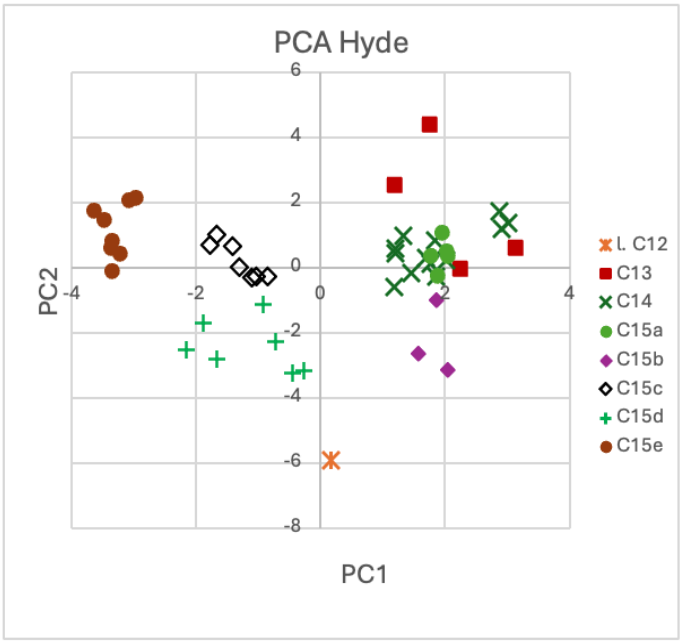


Figure 7.40 Hyde PCA bi-plot

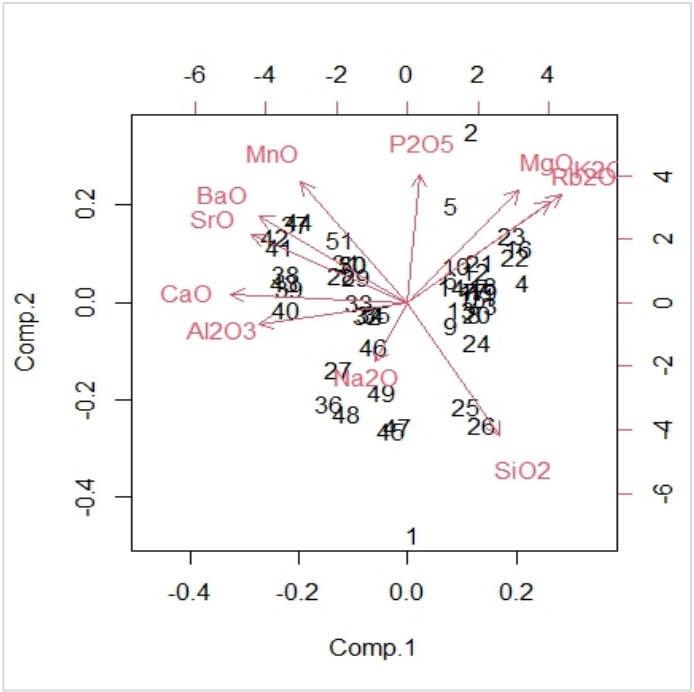


Figure 7.41 Hyde vector graph showing loadings for PC1 and PC2

Although the data points from the 13th and 14th century, and C15a from the 15th century are shown overlapping on the PCA bi-plot, reference to the compositional table below (table 7.15) shows that there are slight variations in the compositions.

7.5.5 The main compositional points for each grouping

The main compositional points for the groupings from all date ranges are presented (table 7.15) with a short discussion for each grouping.

Table 7.14 Average wt% of main discriminating oxides with standard deviation (SD) for Hyde. CS = no. of coloured samples

Group	No	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SrO	BaO	SiO_2	P_2O_5	CaO: K_2O	CS
C12	**1**	**3.59**	**7.16**	**0.50**	**1.30**	**9.86**	**1.59**	**0.79**	**3.27**	**0.07**	**0.04**	**68.02**	**2.63**	**2.7**	**1**
C13	**4**	**12.05**	**1.20**	**0.33**	**5.48**	**13.31**	**0.87**	**1.57**	**1.40**	**0.10**	**0.23**	**58.59**	**4.43**	**1.1**	**0**
SD		3.89	2.69	0.10	2.23	1.56	0.34	0.57	0.86	0.03	0.15	5.01	0.97	0.74	
C14	**13**	**11.08**	**1.12**	**0.25**	**5.14**	**14.67**	**0.94**	**1.27**	**1.75**	**0.09**	**0.15**	**59.02**	**4.05**	**1.4**	**0**
SD		1.60	0.37	0.08	0.66	1.37	0.18	0.08	0.39	0.01	0.02	1.58	0.77	0.28	
C15a	**5**	**11.24**	**1.86**	**0.28**	**5.94**	**14.40**	**1.05**	**1.22**	**1.81**	**0.09**	**0.13**	**57.67**	**3.80**	**1.3**	**0**
SD		0.67	0.27	0.08	0.34	1.50	0.32	0.06	0.38	0.01	0.02	1.34	0.53	0.19	
C15b	**3**	**8.03**	**2.12**	**0.15**	**2.12**	**12.88**	**0.7**	**1.07**	**1.93**	**0.07**	**0.12**	**68.75**	**3.42**	**1.6**	**0**
SD		0.66	0.00	0.00	0.84	0.44	0.09	0.21	0.41	0.02	0.02	1.68	0.73	0.16	
C15c	**7**	**6.86**	**2.27**	**0.18**	**4.12**	**22.70**	**0.83**	**1.30**	**1.85**	**0.13**	**0.26**	**54.68**	**4.22**	**3.3**	**7**
SD		0.47	0.40	0.10	0.17	0.94	0.13	0.22	0.05	0.03	0.07	1.63	0.69	0.35	
C15d	**7**	**4.42**	**1.61**	**0.28**	**2.75**	**21.19**	**0.64**	**0.97**	**2.49**	**0.10**	**0.19**	**60.97**	**2.95**	**5.4**	**0**
SD		1.18	0.82	0.14	0.75	1.35	0.15	0.17	0.64	0.04	0.05	2.67	0.62	1.69	
C15e	**8**	**7.06**	**1.04**	**0.25**	**3.01**	**21.85**	**0.67**	**2.18**	**4.32**	**0.16**	**0.32**	**55.14**	**3.79**	**3.1**	**0**
SD		0.46	0.30	0.08	0.68	1.23	0.07	0.09	0.48	0.01	0.01	2.26	0.35	0.17	

12th century

As shown in table 7.15, the single sample is a mineral alkali glass with very high levels of sodium and silicon, and low levels of potassium, magnesium and phosphorus.

13th century

C13 has high levels of magnesium, manganese and silicon, and a fairly low level of potassium (table 7.15).

14th century

There is one group from the 14th century comprising 13 samples. As shown in table 7.15, the glasses are characterised by low levels of potassium and high magnesium and silicon. Five glasses are silver stained (H14, H56, H65, H85, H87) but there are no coloured glasses.

15th century

There are five compositional groups dated the 15th century date range, C15a, b, c, d and e:

C15a

As shown in table 7.15, this group is comparable to the 13th and 14th century groups above with a low level of potassium. However, C15a has a higher amount of magnesium and slightly lower silicon and phosphorus than these earlier glasses. There are no coloured glasses in this group.

C15b

As shown in table 7.15, C15b comprises three samples that are characterised by low amounts of potassium and calcium. The glasses also contain high levels of silicon; this might suggest that these glasses are contaminated with corrosion products although H59 and H102 have nearly identical amounts suggesting the high amounts of silicon may be intentional (see table 7.16).

Table 7.15 Hyde; the high amounts of silicon may be intentional

Sample	SiO_2
H54	66.83
H59	69.92
H102, bull's eye	69.49

C15c, d and e

These three 15th century groups are HLLA glasses with high levels of calcium and low levels of potassium but form discrete groupings according to the amounts of manganese, silicon, sodium and aluminium (figures 7.42 and 7.43). C15c has a high amount of sodium derived from an alkali source, which may be from added salt (NaCl) (see section 2.3.6) and all of the glasses in this group are coloured (see table 7.17 below); C15e has elevated levels of manganese, possibly to decolour the glass (see section 9.4.4) and the glasses in this group are colourless (and seven of the eight are silver-stained); C15d has elevated levels of silicon and lower levels manganese and sodium (in most samples) compared with the C15c and C15e. Four of the seven C15e glasses are silver-stained.

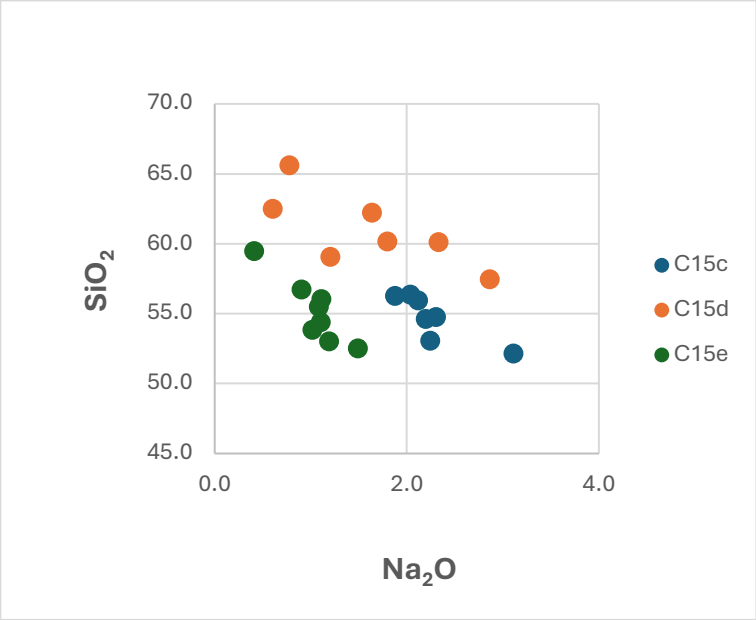


Figure 7.42 Hyde sodium oxide vs. silicon dioxide

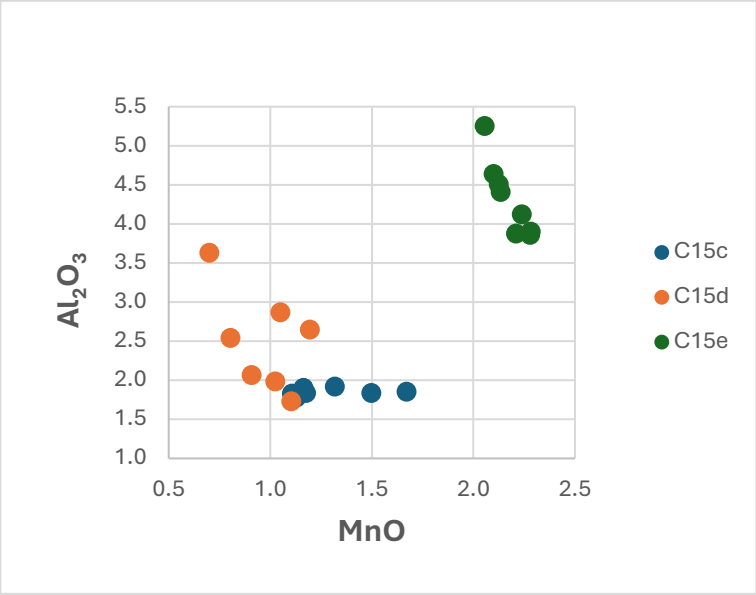


Figure 7.43 Hyde Scatterplot of manganese oxide vs aluminium oxide

7.5.6 Colour

The following table 7.17 shows how each of the coloured glasses from Hyde is coloured. Only two different colours of glass are present in the Hyde groups, blue and red. H41 is the 12th century soda glass and is possibly coloured with recycled Roman glass (for example tesserae) as there was no source of cobalt available in the late 12th century (Gratuze, Pactat and Schibille, 2018, p. 2). The 15th century blue glasses are coloured with trace amounts of cobalt and the red glass (H9) with copper (0.20%).

Table 7.16 Table showing how each of the coloured glasses from Hyde is coloured

Colour	Colourant	Samples	Date range	Information
Blue	CoO (0.07%)	H41	C12	Recycled Roman glass as no C12 source of cobalt (Gratuze, Pactat and Schibille, 2018, p. 2)
	CoO (ave. 0.17%)	H43, H46, H47, H49	C15c	A small amount of ZnO present from CoO source
Flashed red	CuO (0.20%) in a reducing furnace atmosphere	H9	C15c	A small amount of ZnO present
	Red not analysed	H6, H8	C15c	

7.5.7 Cullet

Most of the non-coloured samples in all groups contain trace amounts of cobalt, which is tentative evidence of coloured cullet having been added, and one 15th century sample also contains a small amount of lead (H57).

7.5.8 Summary of results for Hyde

The glasses represent four glazing episodes, the late 12th century, the early to mid-13th century, the mid-14th century and around 1446. Two of the episodes are associated with known building work at the abbey.

The late 12th century glazing episode relates to the reconstruction of the abbey buildings and is represented by a single blue soda glass made using the broad forming method.

The second episode is dated using parallels to the early to mid-13th century. The four fragments have a forest glass composition and are thick, pale green and would have been part of a stiff leaf grisaille window scheme. There is no evidence of forming technique

The third glazing scheme is dated using parallels to the mid-14th century. The 13 fragments are forest glass with evidence of added coloured-cullet in the composition. The glasses are thick and naturally coloured pale green; there are no coloured fragments. Almost half of the glasses are silver-stained, over a third are plain, and the painted decoration suggests a figural window scheme.

The fourth glazing episode is dated to around 1446 when repairs were made to the church following a fire and it seems probable that new windows were installed in the abbot's lodgings at the same time. There are 30 fragments from five compositional groups; C15a and C15b have a forest glass composition and are naturally coloured pale green. The composition of the C15a

glasses show that coloured cullet was probably used; C15b glasses are crown-produced, and this group includes a bull's eye. C15c, C15d and C15e have HLLA compositions, are flat, thin and broad-produced. The glasses that are not deliberately coloured are colourless and have no green tint. Many of the 15th century glasses are decorated with architectural motifs and the glasses probably formed a figural window scheme with an architectural setting.

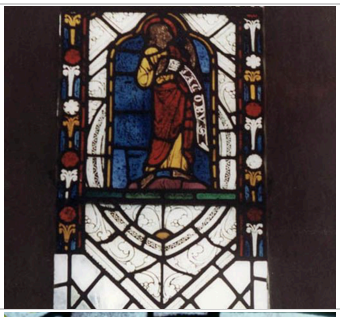
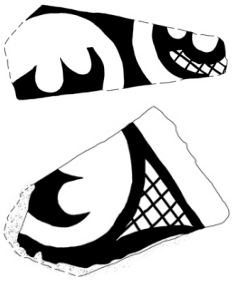
7.6 Louth Park

7.6.1 Stylistic results

There are 49 samples of glass from Louth Park. Thirty-seven samples are dated from the early to mid-13th century and to the 15th century. There is a further group of 12 samples dated to the 14th /15th century based on the TPQ of the red flashed glass in the group and the chemical data. Thirty-five glasses are decorated and 14 are plain.

13th century

There is one chronological group with a total of 24 fragments that date to the early to mid-13th century. Twenty glasses are decorated and four are plain, of which two are coloured, amber, and striated red, Kunicki-Goldfinger type A (Kunicki-Goldfinger et al., 2014, p. 92). There are three fragments decorated with open beading. This is a long-lived motif with examples from the 12th to the 14th century; the parallel from Lincoln Cathedral is early 13th century (e.g. CVMA 2156). L26 is a letter 'C' painted in reserve in the Lombardic style and similar examples, albeit without such an extended serif, are found at Canterbury (CVMA 2929) and Lincoln cathedrals (CVMA 2126), dated to the early to mid-13th century, and a later 13th century parallel is at Credenhill (CVMA 2921). The remaining glasses, two thirds of the group, are decorated with motifs from the stiff leaf grisaille repertoire comprising trefoil heads and stems on a cross-hatched ground. L8 is decorated with a trefoil in the middle of branching stems similar to grisaille decoration at Lincoln Cathedral, dated from the early to mid-13th century (CVMA 2120), and L7 and L10 have berries. These are parallelled with grisaille windows that include those at Salisbury Cathedral, also dated from the early to mid-13th century (CVMA 9954). L11 and L13 are simple, side-facing foliate motifs similar to those in the background grisaille at Stanton Harcourt, dated 1250-80 (CVMA 3312, figure 7.44). These motifs are, however, fruiting, and because they are on a plain ground are dated to a slightly later period than the Louth Park glasses. The above-mentioned Salisbury window is used to suggest an imagined scheme for some of the 13th century stiff leaf grisaille fragments (Appendix 23a).

Figure 7.44 CMVA 3312, Stanton Harcourt		L1, 13 
Figure 7.45 CMVA 11658, Warwick St Mary		L20
Figure 7.46 CMVA 9032, Great Malvern Priory		L28
Figure 7.47 Baker, 1978, pl. 63, Clavering		L29

14th / 15th century

The 14th /15th century group comprises 12 fragments, seven of which are decorated and five are plain, which includes one flashed red glass (L31). Three glasses in the group are painted with decoration with no direct parallels found. L21 and L22 have the same patterning and may be border quarries although the cursive lines may also depict wavy hair similar to that in a figural window at Holy Trinity in York, dated to 1471 (CVMA 18358). L20 may also be a border pattern but has aspects of the nimbus from Beauchamp Chapel, dated 1447-64 (CVMA 11658, figure 7.45). There are three glasses with cross-hatching (L40, L41, L42), and L15 is decorated

with a partial trefoil on a cross-hatched background. Although decorated with typical 13th century grisaille motifs these are probably all replacement glasses, evident from the chemical compositions. Thus, combined with the three glasses with no direct parallels, the dating of the group to 14th /15th century is based on the TPQ of the red flashed glass (late 14th century) and the chemical data, that shows that the glasses have a high calcium composition but are not HLLA.

15th century

As shown in table 7.18, there are 13 fragments in the group dated to the mid-15th century comprising eight decorated glasses including one blue (L34) and two silver-stained (L29, L30), and five plain glasses (L37, L38, L702, L714, L719). The decorated glasses may have been part of a figural window similar to those at Great Malvern Priory, dated to the mid-15th century (e.g. CVMA 11090), Clavering, dated to around 1450 (e.g. CVMA 25566) and Wrangle, dated 1410-30 (e.g. CVMA 23380), that show figures against an architectural backdrop. L34 is coloured blue and depicts drapery, and the architectural motifs seen on L27 and L30 are stipple shaded in typical 15th century fashion. The latter sample is also highlighted with silver stain. L28 shows a partial tonsured head, also stipple-shaded, and much like that depicted at Great Malvern Priory, dated to the mid-15th century (e.g. CVMA 9032, figure 7.46) and in the north window in the nave at St Martin-le-Grand, dated to around 1442 (CVMA 18154). L29 is a partial silver-stained rosette that can be compared with an example decorating a robe worn by God, shown in the form of a human in a window at Clavering, dated to around 1450 (Baker, 1978, pl.63, figure 7.47). The above-mentioned window from Malvern Priory is used to suggest an imagined scheme for some of the 15th century decorated glasses (Appendix 23b).

The summary table 7.18 shows that the glasses in the assemblage from Louth Park Abbey represent three glazing episodes, the early to mid-13th, the 14th/15th and the first half of the 15th century.

Table 7.17 Louth Park, summary of dating using parallels

Date range	No. samples	Stylistic dating
C13	24	Early-mid C13
C14/15	12	C14/15
C15	13	Mid C15

7.6.2 Refining the dating using EIDF for Louth Park

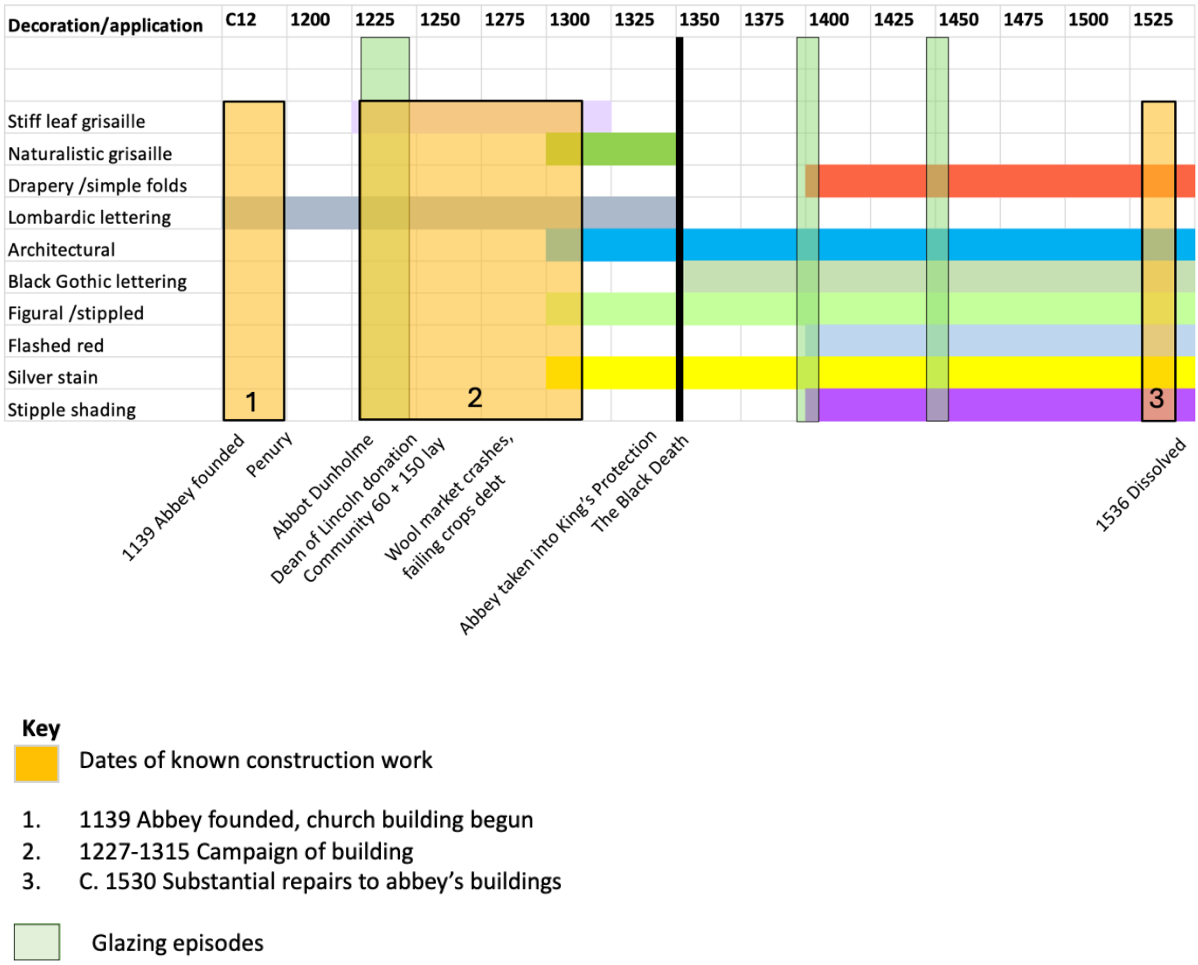
Using EIDF, figure 7.48, the dating of the glasses from Louth Park may be further refined by correlating with relevant building work and events at the abbey.

- The TPQ of the 13th century glasses can be correlated with the start of the campaign of building in 1227 and the TAQ is dated by the parallels to the mid-13th century.

- There is no known construction work or events at the abbey that tie in with the second glazing episode therefore the 14th /15th century date remains unchanged

- Although in the first half of the 15th century the abbey was prosperous there are no references to building work or glazing in this period that might refine the dating, thus the dating of the 15th century glasses remains unchanged

- There are no glasses in the groups that relate to the substantial repairs in the early 16th century



Key

Dates of known construction work

1. 1139 Abbey founded, church building begun
2. 1227-1315 Campaign of building
3. C. 1530 Substantial repairs to abbey's buildings

Glazing episodes

Figure 7.48 Louth Park Evidence Informed Dating Framework

The new dating using evidence from EIDF for Louth Park is shown in table 7.19

Table 7.18 New dating using evidence from EIDF for Louth Park

Date range	No. samples	Revised EIDF dating
C13	24	1227-mid C13
C15	12	C14/15
C15	13	Mid C15

7.6.3 Technical results for Louth Park

The condition of the assemblage is very mixed: the majority of the earlier 13th century glasses are corroded, eight severely and four are in good condition, while the majority of the later glasses are in good, uncorroded condition with only a few more heavily weathered examples. It is probable that localised conditions in the burial environment have played their part in the differences seen here, particularly the 13th century groups whereby some clusters of glass may have been more exposed to ground water, for example, while other glasses were protected. It is noted that few of the fragments have weathered crusts and there is very little flaking; overall, the level of corrosion for many glasses is not severe.

There are 40 glasses with at least one grozed edge and 15 original quarry shapes are discernible, seven in the 13th century groups (L11, L16, L18, L9, L19, L43, L3) and eight in the later dated groups (L39, L21, L22, L31, L734, L806, L38, L719). An interesting freehand-shaped glass in the 15th century group is the upper portion of a monk's tonsured head (L28) and other original shapes include rectangular border glasses, triangular and a shield-shape. Ten of the 13th century glasses and eight of the later-dated glasses are pitted or have a lead shadow demonstrating some degree of weathering while installed.

Across the 13th century group, the thickness averages 3.3 mm. Two plain glasses, L35 and L36 each taper 5-2 mm demonstrating crown production. Glasses in the 15th century group have an average thickness of 2.2 mm, and the 14th /15th century glasses have an average of 3.3 mm. This is higher than the 15th century average, and in accordance with a general trend of decreasing thickness over time. It thus validates the 14th /15th century date that had been allocated based on the TPQ of the red flashing and the chemical composition. There are eight glasses that have evidence of broad production in the form of indents on their exterior sides from the floor of the flattening furnace, two are dated to the 13th century (L26, L44) and six to the later dated groups (L15, L21, L822, L37, L38, L719). The colour of the paint for all glasses is red-brown and there are two examples of smear shading in the 14th /15th century group (L15, L40), and two examples of stipple shading (L27, L28) and silver staining (L29, L30) in the

15th century glasses. L26 is a 13th century single letter 'C', in reserve and is interesting because it was produced using a negative stencil, the only example in the study. The illustration (figure 7.26) shows the jagged cut-out lines of the 'mask' (in this example, the letter C).

Figure 7.49 Jagged cut-out lines of the 'mask' on L26 (Louth Park), which is the only example using a stencil in the study

Four replacement glasses are evident in the 14th/15th century group, which are painted with motifs typical of 13th century grisaille (see Bordesley B26 as another example of a replacement glass). There are three glasses with cross-hatching and a stiff leaf foliate motif (L40, L41, L42, L15). The replacement of broken glasses and also of their mending is discussed in section 4.2.1.

7.6.4 Compositional results for Louth Park

The 13th and 14th/15 glasses are forest type, the latter group having high levels of calcium, and the 15th century glass is HLLA. The discriminating elements that best show the different groupings for Louth Park are magnesium and silica.

The scatterplot of magnesium oxide (MgO) vs. silicon dioxide (SiO_2) (table 7.50) shows that there are five compositional groupings in the group of glasses from Louth Park, three in the 13th, one in the 14th/15th century and one in the 15th century. These groupings represent three glazing episodes at the abbey. The 13th groups are compositionally close although they are more distinctive in figure 7.51, which shows the glasses from this date range only for magnesium oxide vs. silicon dioxide. The amounts of sodium for these earlier groups are however different: C13a has an average of 3.77%, with one fragment (L1) measuring over 6%; the C13b glasses are below detection or close to the limit and the level for C13c is detected at around 2%. The PCA results, however, do not observe the more nuanced compositions as described above, and the 13th glasses are shown clustered (Appendix 14).

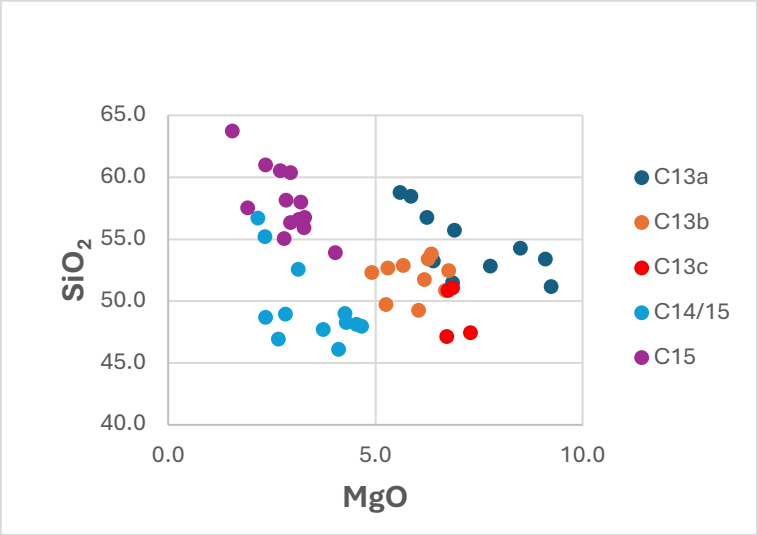


Figure 7.50 Louth Park Scatterplot magnesium oxide vs. silicon dioxide

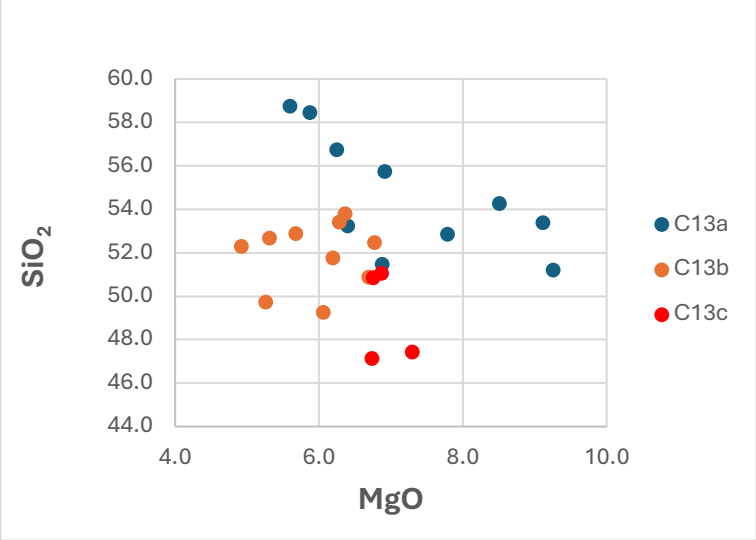


Figure 7.51 Louth Park Scatterplot magnesium oxide vs. silicon dioxide

7.6.5 The main compositional points for each grouping

The main compositional points for the groupings from all date ranges are presented (table 7.20) with a short discussion for each grouping.

Table 7.19 Average wt% of main discriminating oxides with standard deviation (SD) for Louth Park. CS = no. of coloured samples

Group	No	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SrO	BaO	SiO_2	P_2O_5	CaO: K_2O	CS
C13a	**10**	**11.7**	**3.77**	**0.39**	**7.25**	**13.41**	**0.82**	**1.6**	**1.55**	**0.06**	**0.19**	**54.61**	**4.26**	**1.2**	**0**
SD		3.00	1.33	0.07	1.33	1.23	0.35	0.29	0.27	0.01	0.11	2.71	1.04	0.34	
C13b	**10**	**13.9**	**1.17**	**0.28**	**5.95**	**16.36**	**1.14**	**1.14**	**2.52**	**0.08**	**0.18**	**51.92**	**4.94**	**1.2**	**0**
SD		2.09	0.27	0.09	0.63	0.85	0.27	0.32	0.66	0.01	0.09	1.52	0.99	0.21	
C13c	**4**	**15.4**	**1.91**	**0.34**	**6.91**	**15.57**	**0.68**	**1.39**	**1.77**	**0.08**	**0.28**	**49.13**	**6.03**	**1.0**	**2**
SD		2.62	0.26	0.05	0.26	1.14	0.06	0.07	0.02	0.02	0.09	2.12	0.46	0.22	
C14/15	**12**	**13.9**	**0.69**	**0.08**	**3.43**	**20.90**	**0.77**	**0.13**	**3.42**	**0.15**	**0.58**	**49.69**	**4.78**	**1.5**	**2**
SD		1.23	0.00	0.10	0.94	1.94	1.12	0.25	0.54	0.02	0.11	3.33	1.28	0.18	
C15	**13**	**4.03**	**2.15**	**0.40**	**2.86**	**22.52**	**0.82**	**1.10**	**2.83**	**0.12**	**0.25**	**58.00**	**3.39**	**6.1**	**22**
SD		0.76	0.74	0.11	0.64	1.38	0.13	0.23	0.58	0.03	0.06	2.74	0.84	1.47	

13th century

There are three compositional groups dated to the 13th century, C13a, b and c (table 7.2).

C13a

C13a comprises 10 samples that are characterised by high levels of magnesium, manganese and also sodium, which has an average amount of 3.77%, but there are several samples with much higher amounts: L1 (6.37%), L16 (5.12%) and L13 (4.45%) and L19 (4.41%). Although the overall average for potassium is low there are also three samples with a much higher amount, averaging 15.93% (L12, L35, L36). These samples also contain less calcium than the other glasses in the group.

C13b

C13b is a group of 10 samples with a high level of magnesium. L2 and L8 have similar compositions and appear to be from the same sheet of glass.

C13c

C13c comprises two coloured glasses, striated red (Kunicki type A) and amber, and two colourless glasses. They have low levels of silicon and high levels of potassium, magnesium, manganese and phosphorus. Sodium, as discussed above, is just below 2%. The coloured glasses are listed in table 7.21 and discussed below.

C14th/15th century

C14/15 is a large group of 12 samples and, as shown in table 7.20, is notable for its high calcium content and low silica. Two plain samples, L806 and L822 are particularly high in phosphorus (6.58% and 7.19%) and may have surface enrichment of phosphorus due to corrosion. One coloured fragment (L31) is flashed red. The analysis of the red layer was not undertaken, and no data is available for the colourants.

15th century

The group of 13 samples has an HLLA composition with high calcium and silica, and potassium (table 7.20). There is one blue sample, L34, see table 7.21 below.

7.6.6 Coloured samples

The following table 7.21 shows how each of the intentionally coloured glasses from Louth Park is coloured.

Table 7.20 Table showing how each of the intentionally coloured glasses is coloured

Colour	Colourant	Samples	Date range	Information
Striated red	Red not analysed	L32	C13c	Kunicki-Goldfinger type A
Flashed red	Red not analysed	L31	C14/15	Kunicki-Goldfinger type B-2
Amber	Reducing atmosphere, possibly carbon added	L33	C13c	(Mason, n.d.)
Blue	CoO (0.23%)	L34	C15	ZnO and CuO present in small amounts

There are only four coloured samples in the Louth Park group of glasses; the single amber glass is coloured in a reducing furnace atmosphere and accordingly, sample (L33) contains a high level of potassium (18.38%) as flux to enable the glass to melt at a lower temperature. The blue glass (L34) is coloured with a trace amount of cobalt plus a small amount of zinc, and copper which is at the limit of detection; cobalt ore may have been used to colour the glass. The red areas of the striated and flashed red glasses were not analysed.

7.6.7 Cullet

There is evidence for the use of cullet in the 13th century glasses by way of trace amounts of cobalt in approximately half of the non-coloured glasses in this date range. In the 14th/15th century group three glasses (L734, L806, L822) contain trace amounts of lead (average 0.29%), which may indicate the addition of recycled window glass with lead came attached or painted

with lead paint, to the melt. There is no evidence for the use of coloured cullet in the non-coloured 15th century glasses.

7.6.8 Summary of results for Louth Park

There are three glazing episodes at Louth Park, represented by 49 samples that are dated, 1227-the mid-13th, 14th/15th and the mid-15th century.

The earliest episode at Louth Park comprises four compositional groups concomitant with the early stage of the 13th century building campaign and are dated to the second quartile of the 13th century. There are 24 fragments of forest glass, which are thick and pale green. These glasses are decorated with stiff leaf grisaille motifs and were part of a stiff leaf grisaille decorative scheme. There are examples of both broad and crown production, and tentative evidence of the use of coloured cullet.

The second episode is dated to the 14th /15th century, and there are 12 fragments all of which have a high calcium forest glass composition. Four of the glasses are replacements decorated with stiff leaf grisaille motifs and the remainder are probably border patterns, for which dated parallels could not be found. The fragments from this glazing episode are predominantly naturally coloured pale green with one flashed red glass present in the group. They are relatively thick and some show evidence of crown production. There is tentative evidence of the use of coloured cullet.

The third glazing episode is dated by way of the parallels to the mid-15th century. The glasses have an HLLA composition, and the fragments are refined and very pale green although not colourless. The paucity of coloured glasses suggests that this was a simple, relatively monochromatic scheme.

7.7 Rievaulx

7.7.1 Stylistic results

There are 58 samples of glass from Rievaulx dated to the broad date ranges, 13th, 13th/14th, 14th and 15th centuries. Fifty-four glasses are decorated and four are plain.

13th century

There is one group that comprises 13 glasses that are dated to the early to mid-13th century. Twelve of the glasses are decorated including two coloured, green and murrey (R2, R58), and there is one colourless plain glass (R62). The majority of the glasses are decorated with stiff leaf grisaille motifs of single and double-headed trefoils, curling stems and cross-hatching (e.g. R7). There are similar arrangements at Lincoln (e.g. CVMA 2130) and Salisbury Cathedrals (e.g.

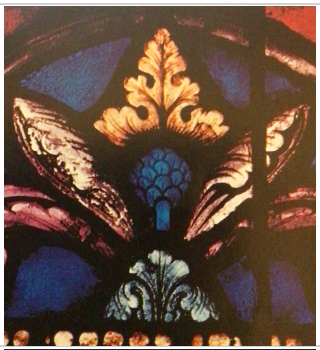
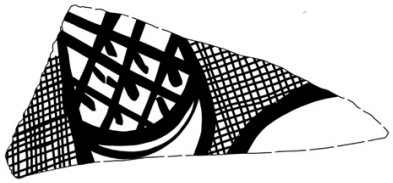
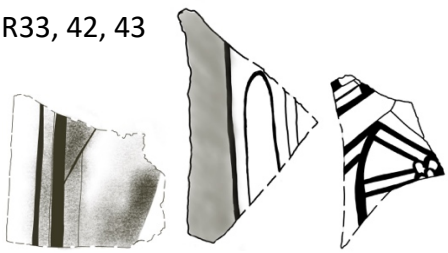
CVMA 9954), dated to the early to mid-13th century. R13 is an unusual grisaille motif depicting a variation on an acorn, or possibly a pineapple based on the detailing of the individual fruits. There are no direct parallels, but similar detail can be seen on fruit in the border of the Trinity Chapel window at Canterbury Cathedral, dated to the early 13th century (Baker, 1978, pl. 1) (figure 7.52).

There are three other decorated fragments: R2 is a stylised foliate motif remaining as a raised outline in the green glass (see section 2.5.2). There are no direct parallels, but the decoration has aspects of the foliage in the Adam window at Canterbury Cathedral that is dated 1213-20 (CVMA 748) and a window in the Angel Choir at Lincoln Cathedral that is dated 1250-80 (CVMA 24526). R2 was retrieved from the north transept of the church and is the only sample from Rievaulx with a known find-spot in the church. Further find-spots of 13th century glasses are the Chapter House, where R6 was retrieved and the west range where R14 was retrieved. All other glasses retrieved from the west range date to the 15th century and may be connected with the late 15th century glazing of the cloister. R14, which is decorated with stiff leaf grisaille may therefore be an example of an older 'sacrificial' glass reused in the border of a newer window (Mason, n.d.).

R19 is decorated with linear stickwork much like the detailing on Jared's robe in the Genealogy of Christ series in Canterbury Cathedral, dated to the late 13th century (Michael, 2019, p. 32) and also the border decoration in the Chancel south window at Stanton Harcourt, dated 1250-80 (CVMA 3312). R58 is murrey coloured and painted with drapery folds similar to the cloak folds in the Genealogy of Christ windows at Canterbury Cathedral, dated to the early 13th century (Michael, 2019, p. 39) (figure 7.53).

13th / 14th century

There are two glasses in the 13th/14th century group. Both glasses are decorated with naturalistic grisaille designs, R17 with the painted outline of oak leaves similar to examples at York Minster Chapter House (e.g. CVMA 22238) and Merton College (e.g. CVMA 3995) (figure 7.54) that are dated to the early 14th century, and R44 is a quatrefoil in reserve and similar to an example at Eaton Bishop also dated to the early 14th century (Baker, 1978, pl. 42). A late 13th century parallel at Chartham is a three-leaf corner motif in reserve (Marks, 1993, fig 121).

Figure 7.52 Baker, 1978, pl. 1, Canterbury Cathedral		R13 
Figure 7.53 Michael, 2019, p. 39, Canterbury Cathedral		R58
Figure 7.54 CVMA 3995, Merton College		R17
Figure 7.55 CVMA 4035, Merton College		R26, 35
Figure 7.56 CVMA 18166, St Martin-le-Grand		R33, 42, 43 

14th century

There are 21 glasses that comprise one group that dates to around the mid-14th century. There are 20 decorated glasses of which nine are coloured, amber (R1), blue (R53, R51, R52, R63), green (R45, R55, R56) and striated red (R50) (Kunicki-Goldfinger et al. type A). There is also one undecorated green glass (R54).

Decoration includes a naturalistic grisaille quatrefoil (R1, which is similar to R44, dated to the 13th/14th century), open beading, border patterns of stylised spirals and micro architecture. Nearly half of the glasses are decorated with foliate designs or diaper patterns, most of which are coloured with variations on a seaweed pattern (e.g. R53). The fragments R11, R25, R26 and R35 have similar styling, painted in reserve with motifs that include a fleur de Lys, a speckled bird with smear shading and a foliate design. These are probably border motifs similar to those seen at Eaton Bishop, dated 1330-35 (e.g. CVMA 20124), Merton College 14th century (CVMA 4035) (figure 7.55) and York Minster where comparable birds can be seen in the Pilgrimage window (SGN); the latter two parallels are dated to the early 14th century. R35 is similarly painted in reserve and depicts architectural crockets. R24 is a face with distinctive hatching painted around the eyes, nose and mouth. This style of facial detailing is seen more widely in the late 14th and 15th century, however the parallel from Tewkesbury Abbey, dated to around 1338-40 (e.g. CVMA 1762) has the same strong outlines to the facial features although in this example, depth is achieved by way of smear shading as opposed to the hatching seen on the sample. There are find-spots for two of the glasses, these are R4, which was retrieved from the cloister and R63, which was retrieved from the Chapter House. The presence of coloured glasses, border and background designs, a figure represented by the face, and micro-architecture suggests that the glasses were part of a figural scheme similar to the panels in the York Minster Pilgrimage window previously mentioned.

15th century

There are 23 samples in one chronological group that dates to the mid to late 15th century. Twenty one samples are decorated, of these four are silver stained (R32, R33, R34, R37) and one is flashed red (Kunicki-Goldfinger et al. type B-2) (R48). Two samples are plain (R60, R61).

Nearly one third of the glasses depict micro-architecture although the motifs on two of these are unclear (R40, R42). Several fragments are painted with diaper decoration. Together, the decoration on this group of glasses suggests a figural scheme with an architectural backdrop similar to those at St Martin-le- Grand, dated to around 1442 (e.g. CVMA 18166) (figure 7.56), Holy Trinity in Goodramgate in York, dated to 1470-75 (CVMA 18385), and East Harling, dated around 1480 (e.g. CVMA 15854). The seven glasses retrieved from the west range and which may be connected with the glazing of the cloister in the late 15th century are R34, R38, R39, R40, R41, R42, R48. An imagined scheme using these fragments and other 15th century samples is the East Harling window, mentioned above (see Appendix 24).

The summary table (7.22) shows that based on the dated parallels the glasses in the assemblage from Rievaulx Abbey represent four glazing episodes: early to mid-13th, 13th/14th, mid-14th and mid-to-late-15th centuries.

Table 7.21 Rievaulx, summary of dating using parallels

Date range	No. samples	Stylistic dating
C13	12	Early to mid C13
C13/14	2	C13/14
C14	21	Mid C14
C15	23	Mid-late C15

7.7.2 Refined dating using EIDF for Rievaulx

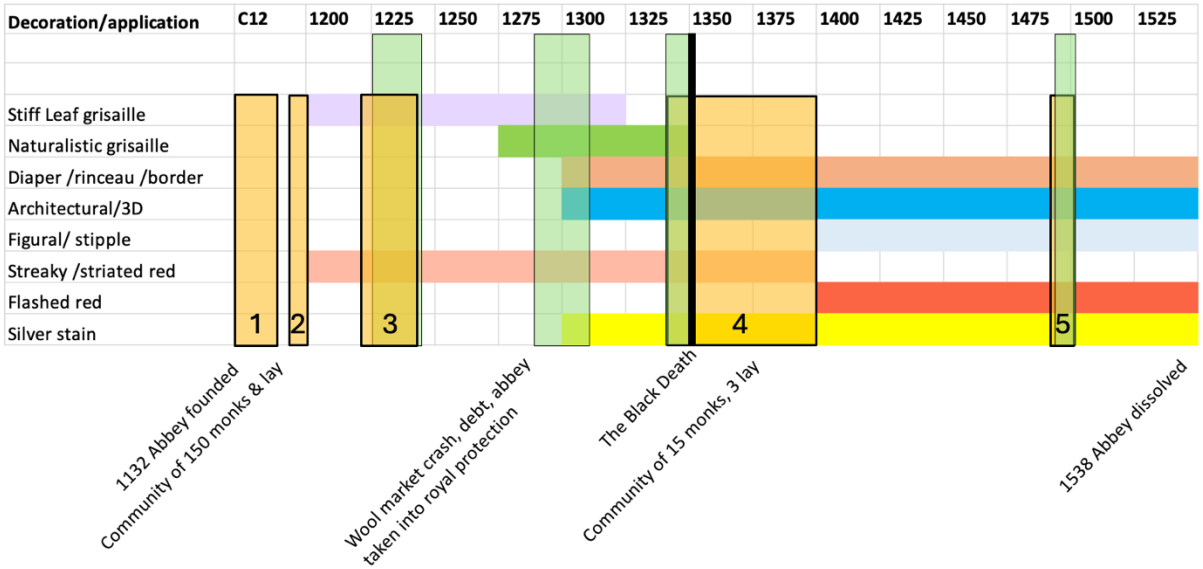
Using EIDF (fig 7.57), the dating of the glasses may be further refined by correlating with relevant building work and events at the abbey.

- One mid-13th century glass that was retrieved from the north transept may be connected to the extension to the church in 1220-39, and there are glasses of the same date retrieved from the Chapter House and the west range. Hence, the first half of the 13th century dating can be refined to the date of the church extension. This evidence also demonstrates that glazing was undertaken across various abbey buildings at the same time.

- There is no evidence of building work that relates to the 13th/14th century window glass thus the dating remains unchanged.

- Between 1340 and around 1400 key buildings in the complex were remodelled; there are no later 14th century glasses that can be linked to this remodelling, however the dating of the glasses by the parallels to the mid-14th century can be slightly refined to the 1340s, to the period before the Black Death that arrived in England in 1348 (see chapter three, section 3.6.3).

- Extensive remodelling of the buildings in the nucleus of the complex was undertaken in the late 15th century, this included new glazing in the cloister, remodelling of the monk's infirmary around 1490, and around 1500 the church was remodelled and the windows enlarged. The only find-spots for the 15th century glasses are the west range where seven samples were retrieved and these may relate to the cloister glazing. The original locations of the remaining 16 glasses in the 15th century date range are unknown, although, as demonstrated here at Rievaulx and at Bordesley, glazing across more than one building concomitantly was not unusual. It is feasible therefore to use the EIDF evidence to refine the dating of the 15th century samples to 1490-1500



Key

Dates of known construction work

1. C. 1130-60 Church, west and east ranges built
2. Late C12 Refectory built
3. 1220-39 Church extended and remodelled
4. 1340-1400 Church and Chapter House remodelled, new clerestory, E and W windows installed
5. 1490s Infirmary remodelled as abbot's lodgings, church remodelled, windows enlarged, new glazed cloisters

Glazing episodes

Figure 7.57 Rievaulx Evidence Informed Dating Framework

The new dating of the glasses from Rievaulx using EIDF is presented in table 7.23

Table 7.22 Rievaulx new dating of the glasses using EIDF

Date range	No. samples	Stylistic dating
C13	12	1220-39
C13/14	2	C13/14
C14	21	1340s
C15	23	1490-1500

7.7.3 Summary of technical results for Rievaulx

The appearance of the glasses varies widely in terms of weathering; most of the 13th and 14th century glasses are severely corroded while many of the 15th century glasses are in good, relatively uncorroded condition. Of note is R2, a heavily degraded 13th century green glass displaying a raised impression of its decoration in a similar manner to ALC 57b. Twelve glasses have evidence of in-situ weathering, predominantly from the later periods and demonstrates that these glasses were weathered while installed. Forty-four glasses from all date ranges have grozed edges and there are 22 identifiable, original shapes in total: four amongst the 13th century groups, 11 amongst the 14th century groups and seven from the 15th century groups. Shapes include rectangular border fragments, ogee, square, triangular, irregular, and a freehand shape outlining a depiction of a hand (R21).

Although many of the fragments show bubble alignment, none are conclusive of forming technique; R22 contains many small bubbles with no obvious alignment and R39 has bubbles up to 2.8 mm long and 1.5 mm wide. These large bubbles may indicate an early stage of the melt before gases have escaped. There are five glasses, however, that demonstrate broad glass production by way of fire rounded edges, one 14th century glass (R52), and four 15th century glasses with indents from the floor of the flattening furnace (R41, R43, R32, R33). There is no evidence of crown production and although the 13th century glasses are very thick with an average depth of 3.7 mm, there are no tapering fragments that might corroborate crown production. Both 13th/14th and 14th century groups average 3.3 mm thick, and in the 15th century the average is 2.2 mm demonstrating a decreasing thickness over time.

The range of colours in the assemblage is diverse: murrey and green in the 13th century; amber, blue, striated red and green in the 13th/14th and 14th century, and flashed red in the 15th century. The naturally coloured glasses are pale green with 17 colourless glasses in the 15th century groups. The paint colour is predominantly red-brown with five glasses in the 15th century groups with paint that is dark brown (R27, R28, R37, R39, R41). These glasses were

probably part of the same window scheme (perhaps not dissimilar to the 15th century window at St Martin-le-Grand, York (CVMA 18166). There are seven examples of stipple shading in the 15th century group (R33, R34, R38, 40, R41, R42, R43) and four examples of silver staining (R32, R33, R34, R37), and for the decoration of the 14th century glasses, stickwork and painting in reserve techniques were used (e.g. R26, R53). There is a good example in the assemblage of a glass with a complete technical profile, R52, which is a 14th century blue, broad glass, irregularly shaped and decorated with red-brown paint in reserve with stickwork detailing.

7.7.4 Chemical compositional results for Rievaulx

Glasses from the 13th, 13th/14th, 14th century groups, and two groups from the 15th century are forest type, and the remaining two groups from the 15th century are HLLA. The discriminating elements – or variables, that best show the different groupings for Rievaulx are potassium, calcium, phosphorus manganese and silica.

The scatterplots of potassium oxide (K_2O) vs. calcium oxide (CaO) (figure 7.58 and 7.59), manganese oxide (MnO) vs. silicon dioxide (SiO_2) (figure 7.60), potassium vs. magnesium (figure 7.61) and calcium oxide vs. phosphorus pentoxide (figure 7.62) show that there may be up to nine compositional groupings, one each in the 13th and 13th/14th, three in the 14th century and four in the 15th century. However, there is much overlapping of the data points in the 14th and 15th century groups although the scatterplots for the separate 14th and 15th century groups show the groupings more distinctly (figures 7.59 to 7.62). The groupings are also shown clustered on the PCA bi-plot (see Appendix 15).

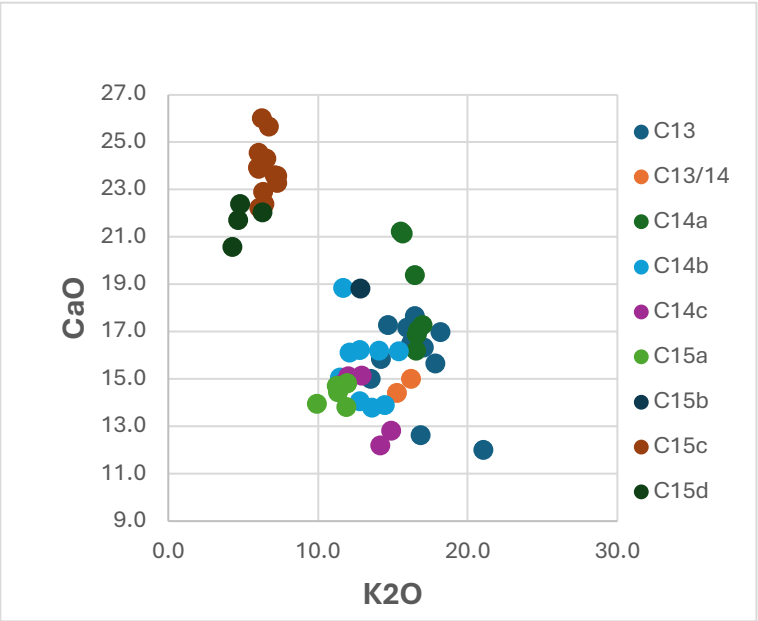


Figure 7.58 Rievaulx, potassium oxide vs. calcium oxide

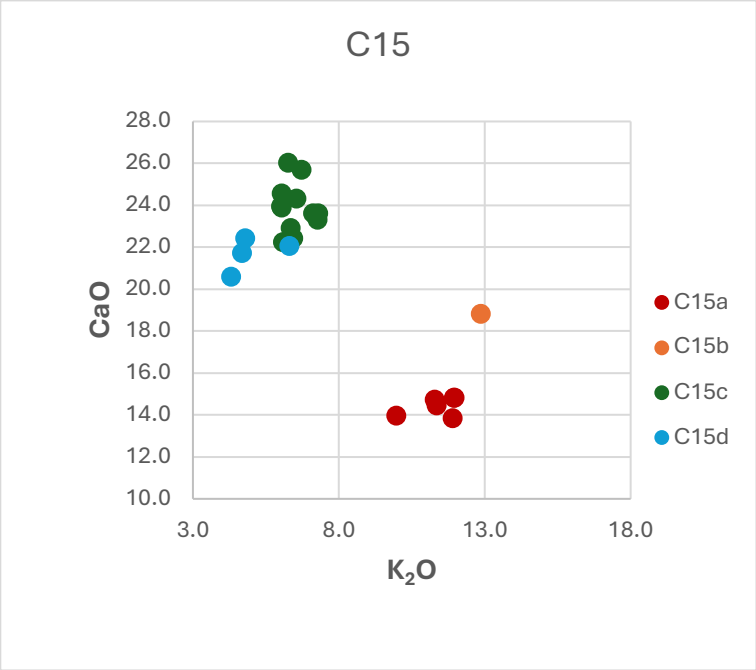


Figure 7.59 Rievaulx C15 groups, potassium oxide vs. calcium oxide

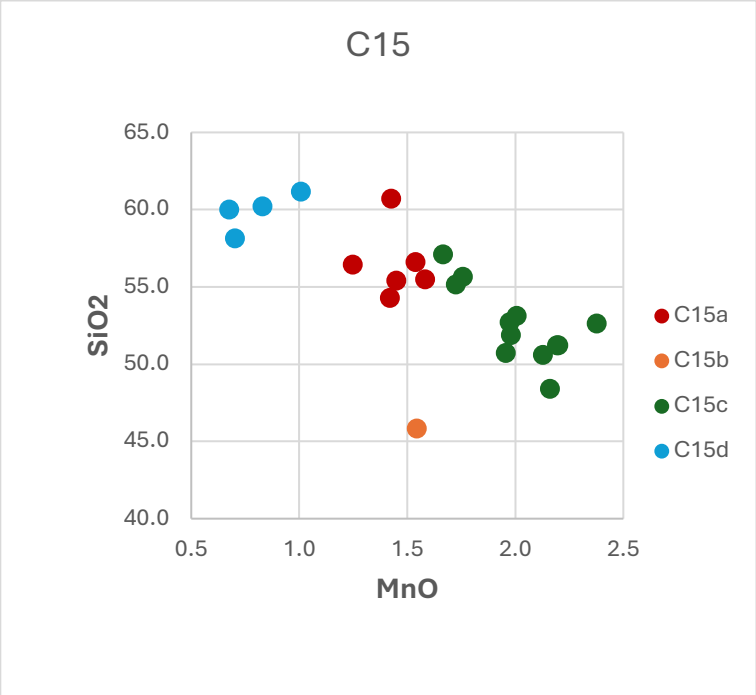


Figure 7.60 Rievaulx C15 groups, manganese oxide vs. silicon dioxide

Figures 7.31 and 7.32 show how the 15th century groups are differentiated by the ratios of potassium and calcium, and manganese and silicon: C15a and C15b are forest glasses and C15c and C15d are HLLA glasses. C15a has a lower calcium and higher silicon than C15b, and C15c has higher calcium and lower manganese than C15d.

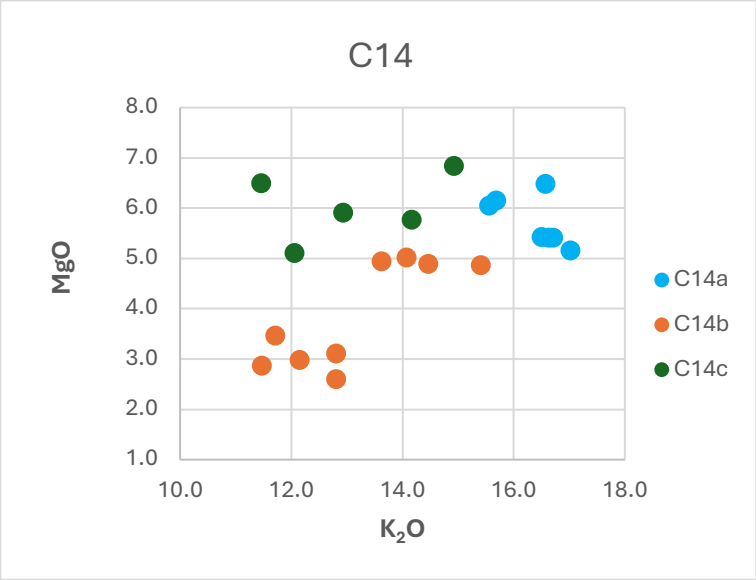


Figure 7.61 Rievaulx C14 groups, potassium oxide vs. magnesium oxide

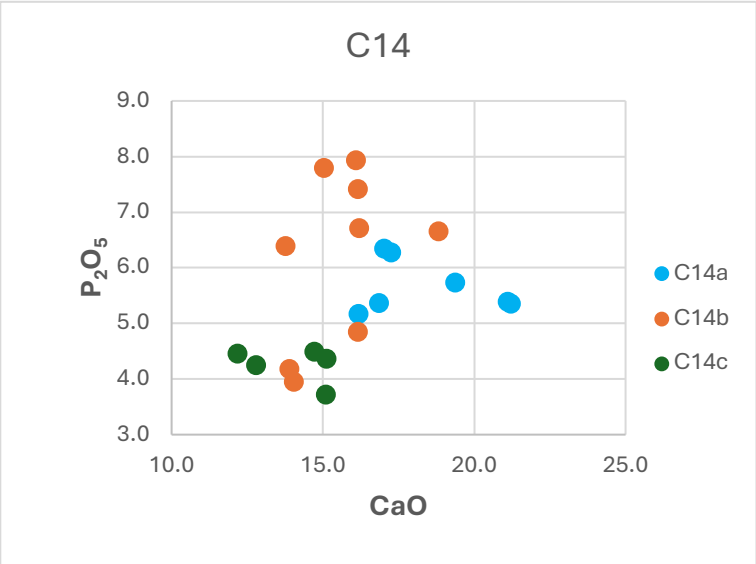


Figure 7.62 Rievaulx C14 groups, calcium oxide vs. phosphorus pentoxide

The 14th century groups are more difficult to differentiate and there are still clusters shown on the scatterplots (figures 7.61 and 7.62), particularly C14b and C14c. However, as with Louth Park above, the sodium and manganese levels for these groups (the averages for which are reported in table 7.24 below) are different (and which are also not observed in the PCA bi-plot): C14b has an average amount of sodium just above detection limit (1.17%) whereas C14c is detected close to 2% and there is twice as much magnesium in 14c compared to 14b.

7.7.5 The main compositional points from the chemical analysis

The main compositional points for the groupings from all date ranges are presented (table 7.24)

Table 7.23 Average wt% of main discriminating oxides with standard deviation (SD) for Rievaulx. CS = no. of coloured samples

Group	No	K_2O	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SiO_2	P_2O_5	Na_2O	PbO	CaO: K_2O	CS
C13	**12**	**16.55**	**4.95**	**15.78**	**1.32**	**0.97**	**2.71**	**49.37**	**6.04**	**1.08**	**0.12**	**1**	**2**
SD		1.99	0.70	1.79	0.36	0.22	0.69	1.83	0.93	0.23	0.93	0.17	
C13/14	**2**	**15.88**	**4.83**	**14.69**	**0.78**	**1.67**	**2.66**	**52.71**	**4.68**	**0.89**	**0.15**	**0.9**	**1**
SD		0.69	0.02	0.42	0.19	0.41	0.89	3.31	1.07	0.10	0.11	0.01	
C14a	**7**	**16.39**	**5.72**	**18.44**	**1.36**	**1.03**	**2.49**	**45.91**	**5.65**	**1.55**	**0.16**	**1.1**	**2**
SD		0.55	0.49	2.11	0.23	0.36	0.40	1.99	0.47	0.30	0.39	0.17	
C14b	**9**	**13.18**	**3.85**	**15.59**	**1.39**	**1.24**	**2.60**	**52.78**	**6.20**	**1.17**	**0.65**	**1.2**	**5**
SD		1.32	1.04	1.61	0.49	0.27	0.40	3.21	1.52	0.31	0.32	0.20	
C14c	**5**	**13.11**	**6.01**	**13.99**	**0.93**	**1.13**	**2.32**	**52.72**	**4.25**	**1.95**	**0.37**	**1.1**	**5**
SD		1.44	0.68	1.39	0.15	0.20	0.40	2.14	0.32	0.30	0.32	0.21	
C15a	**6**	**11.42**	**5.15**	**14.41**	**1.15**	**1.45**	**1.84**	**56.44**	**5.16**	**1.44**	**0.37**	**1.3**	**0**
SD		0.77	0.97	0.44	0.09	0.12	0.31	2.24	0.71	0.38	0.11	0.08	
C15b	**1**	**12.88**	**3.05**	**18.80**	**1.44**	**1.54**	**3.41**	**45.79**	**10.1**	**1.02**	**0.40**	**1.5**	**0**
C15c	**12**	**6.53**	**3.22**	**23.85**	**0.72**	**2.01**	**4.36**	**52.48**	**4.07**	**1.49**	**0.04**	**3.7**	**0**
SD		1.82	0.60	1.79	0.22	0.24	0.69	2.99	1.85	0.40	0.11	0.69	
C15d	**4**	**5.04**	**2.54**	**21.67**	**0.70**	**0.81**	**2.91**	**59.82**	**2.93**	**2.24**	**0.03**	**4.4**	**1**
SD		0.88	0.57	0.78	0.13	0.15	0.82	1.26	0.40	0.31	0.03	0.60	

13th century

As shown in table 7.24, C13 is characterised by high potassium and phosphorus, and low silica and sodium. Although the average Ca:K ratio is equal, one sample (R19) is particularly high in potassium (21.09%) and low in Ca (11.99%) but is otherwise compatible with the rest of the samples in the grouping. The amount of iron in this group is high with low amounts of manganese except for two samples (R19 and R58) that have low iron (average 0.70%) and high manganese (average 1.33%). There are two coloured samples, see table 7.25 below.

13th/14th century

As can be seen in table 7.24, the two samples have very high potassium and manganese, and low sodium and iron and the Ca:K ratio is almost equal. There is one amber coloured glass in the group, see table 7.25 below.

14th century

As shown in table 7.24 there are three compositional groups dated to the 14th century with a forest glass composition:

C14a

Table 7.24 shows that the seven samples in C14a are characterised by high levels of potassium, calcium, magnesium, aluminium and phosphorus and very low silicon. The Ca:K ratio shows a composition that has a slightly higher amount of calcium to potassium. There are two coloured samples, blue and amber, see table 7.25 below.

C14b

As shown in table 7.24, the glasses are characterised by a high level of phosphorus and the Ca:K ratio shows that there is slightly more calcium than potassium. Of note is a very high amount of lead, which is slightly higher in the coloured samples (see table 7.25 below), but nonetheless is also of a significant level in the naturally coloured samples.

C14c

C14c has high magnesium (table 7.24). Three samples are coloured, see table 7.25 below, two of which are compositionally very similar and are probably from the same sheet of glass (R55, R56). As mentioned above, the average sodium level is close to 2%.

15th century

Table 7.24 shows that here are four 15th century groups, two of which have a forest glass composition and two groups that have an HLLA composition:

C15a

C15a is characterised by high magnesium and phosphorus and low potassium. Lead is high in three samples (R23, R30, R31) (ave. 0.37%).

C15b

The single sample (R21) has a very high amount of phosphorus and calcium, and very low silicon. The glass has a calcium-rich composition but is not HLLA, and the high level of phosphorus may be due to surface enrichment from corrosion. The sample also contains high lead (0.40%).

C15c

C15c has an HLLA composition with very high calcium and very low potassium as shown in the high Ca:K ratio. There are also high levels of manganese, aluminium and barium.

C15d

The C15d group also has an HLLA composition with a high Ca:K ratio. Calcium, silicon and sodium are also very high, while potassium, magnesium, manganese and phosphorus are low. There is one flashed red fragment, see table 7.25 below.

7.7.6 Coloured glasses

Table 7.25 shows how each of the coloured glasses from Rievaulx is coloured. There are five different colours of glass present: green, murrey, amber, blue and striated and flashed red.

Two of the green glasses are coloured with iron (R2, R45) and three green glasses are coloured with trace amounts of copper (R54, R55, R56). The green glasses may have been coloured through the addition of copper alloy, probably as scrap or off-cuts. The murrey glasses (R58, R44) are coloured by manganese in an oxidised state and according to Weyl (1951, p. 129) this would have been at a low temperature and probably at the start of the melt. The amber glass (R1) is coloured in a reducing furnace atmosphere (possibly with added carbon) (Paynter and Jackson, 2018, p. 569). There are four blue glasses, which are coloured with trace amounts of cobalt (average 0.125%) as well as significant levels of copper, zinc and lead, which may have entered the melt with the cobalt ore. The striated red glass (Kunicki-Goldfinger type A) (R50) is coloured with a trace amount of copper. The red layer of the flashed red glass (R48) was not analysed.

Table 7.24 Rievaulx Table showing how each of the coloured glasses is coloured

Colour	Colourant	Samples	Date range	Information
Green	Fe_2O_3 (1.06%)	R2	C13	
	Fe_2O_3 (1.50%)	R45	C14b	
	CuO (3.22)	R54	C14c	Very high amounts of CuO
	CuO (3.37) SnO_2 (0.26%	R55		Two of the three samples contain PbO. One sample contains SnO_2
	CuO (3.37)	R56		
Murrey	High MnO (1.63%)	R58	C13	Coloured with manganese in an oxidised state
	High MnO (1.95%)	R44	C13/14	
Amber	Reducing atmosphere, possible added carbon	R1	C14a	
Blue	CoO (ave. 0.13%)	R53	C14a	Significant levels of CuO, ZnO and PbO
	CoO (ave. 0.12%)	R51	C14b	
	CoO (ave. 0.12%)	R52		
	CoO (ave. 0.12%)	R63		
Striated red	CuO (0.23%)	R50		Kunicki-Goldfinger et al. type A
Flashed red	Red layer not analysed	R48	C15d	Kunicki-Goldfinger et al. type B

7.7.7 Cullet

There is limited compositional evidence of the use of coloured cullet in the Rievaulx glasses; only a trace amount of lead is present in six non-coloured glasses and only one non-coloured glass has a trace amount of copper (table 7.26).

Table 7.25 Rievaulx Glazing episode showing evidence for the use of cullet contaminated with lead and copper

Date range	Non-coloured samples	PbO wt%	CuO wt%
C14b	R11	0.49	
	R26	0.81	0.15
C15a	R23	0.35	
	R30	0.30	
	R31	0.46	
	R21	0.40	

7.7.8 Summary of results for Rievaulx

There is one group of 12 glasses that represent the first glazing episode, which is dated to around 1220-39 when the church was extended. The glasses have a forest glass composition, are thick and predominantly naturally coloured pale green. There are also two deliberately coloured glasses: murrey and green. There is no evidence of forming technique in the group. The glasses would have been part of a stiff leaf grisaille scheme and R14 may have been used as a sacrificial border fragment for a newer window, and based on the find-spot, possibly in the cloister.

The second glazing episode is represented by two glasses dated using parallels to the 13th/14th century, and both are decorated with naturalistic grisaille designs. One glass is naturally coloured pale green, and the other is murrey coloured. Both glasses have a forest glass composition and are thick and crown-produced.

The third glazing episode comprises 21 forest glasses from three compositional groups and is dated to the 1340s when the church and other buildings were remodelled. The fragments are thick, and around half are naturally coloured pale green and the remaining half are intentionally coloured amber, blue, green and striated red. There is no evidence of forming technique. The decoration on all of the glasses suggests that they were part of a multi-coloured figural scheme.

The fourth glazing episode is represented by 23 fragments and is dated to around 1490-1500 when some of the buildings were remodelled and new glazing installed. Seven of the glasses have a forest glass composition including one sample that is calcium-rich, and 16 fragments

have an HLLA composition. The decoration on all of the glasses suggests that they were part of a figural scheme of decoration carrying an inscription, perhaps a dedication.

7.8 Whitby

7.8.1 Stylistic results

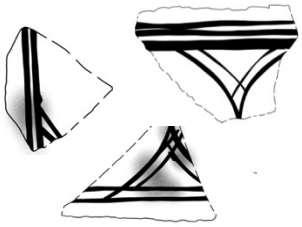
There are 29 samples of glass from Whitby dated using the timeline of decorative motifs to the broad date ranges, the 13th, C13th/14th, 14th and 15th centuries. Twenty glasses are decorated and nine are plain.

13th century

There is one group comprising 10 glasses dating to the early to mid-13th century. Eight glasses are decorated, and two are plain including one coloured blue fragment (W27). There are eight samples decorated with motifs from the stiff leaf grisaille repertoire, of curling stems, berries and trefoils on a cross-hatched ground. Similar schemes are found at Lincoln Cathedral, dated early 13th century (CVMA 10034) (figure 7.63), York Minster, dated 1250-60 (CVMA 3628) and Salisbury cathedral, dated the early to mid-13th century (CVMA 10185). Two glasses (W5, W6) are decorated with open beading, which has parallels from the 12th to the 14th century but there are early to mid-13th century examples at Salisbury Cathedral (CVMA 9954). The Salisbury window mentioned above, is used as an imagined scheme for some of these glasses (Appendix 25).

13th / 14th century

There is one glass decorated with a naturalistic grisaille motif of a veined, three-lobed leaf within strapwork on a plain ground. This motif is found in the late 13th century to early 14th century; the original shape of the quarry is a diamond, and the glass was probably part of a window composed of many similar individual quarries much like the Chapel window at Merton college, dated to the early 14th century (CVMA 4134) (figure 7.64). Some of the panels in the Chapter House at York Minster, dated to the late 13th century have similar motifs although the quarries are more irregularly-shaped (CVMA 22295).

Figure 7.63 CVMA 10034, Lincoln Cathedral		
Figure 7.64 CVMA 4134, Merton College		W8
Figure 7.65 Graves, 2000, fig. 176, p. 379		W17, 18, 19 
Figure 7.66 CVMA 23313, Wrangle.		W16

14th century

There are nine fragments that form one chronological group that dates to the mid-14th century. There are six decorated glasses and three plain coloured glasses, streaky blue and streaky red (Kunicki-Goldfinger et al. type A) with a TAQ of the end of the 14th century. The decorated fragments include two narrow border or edging fragments painted with linear stickwork patterns (W11, W15); one fragment with a possible architectural detail (W7), and three silver-stained grisaille quarries all from the same panel (W17, W18, W19). Here the decoration is of strapwork, and which when joined together would have formed a decorative,

quatrefoil-shaped framework similar to an example from Whitby Abbey now on display in Whitby Museum. These glasses are also similar to fragments from St Andrew's Priory in York that are dated to the mid-14th century (Graves, 2000, P. 379) (figure 7.65).

15th century

There are nine fragments in one group that dates to the early to mid-15th century. Five are decorated, one of which is silver-stained (W14) with a TPQ of around 1310, and four are plain; of these, two are coloured flashed red (Kunicki-Goldfinger type B2) (W21, W24). The decorated fragments include a rosette motif (W16) and micro-architecture (W13, W20, W22), with parallels that include St Martin-le-Grand, dated around 1442 (CVMA 18170), Great Malvern Priory, dated to the early to mid-15th century (CVMA 11090) and Wrangle, which is dated 1410-30 (CVMA 23313) (figure 7.66).

The summary table 7.27 shows the glasses in the assemblage from Whitby Abbey represent four glazing episodes, the early to mid-13th, 13th/14th, mid-14th and early to mid-15th century.

Table 7.26 Whitby Abbey, summary of dating using parallels

Date range	No. samples	Stylistic dating
C13	10	Early-mid C13
C13/14	1	C13/14
C14	9	Mid C14
C15a	9	Early-mid C15

7.8.2 Refined dating using EIDF for Whitby

Using EIDF (figure 7.67) the dating of the glasses may be further refined by correlating with relevant building work at the abbey. There are no findspots for any of the glasses and the only known building work is at the abbey church. As seen at other sites such as Bordesley, glazing episodes were not restricted to single buildings and the glaziers may have worked on several buildings at the abbey simultaneously. Thus, the dates of construction work relating to the church may be of value in refining the dates of the glasses.

- The glasses dated early to mid-13th century tie in with the first phase of building, therefore refining the dating to 1220-35

- The single 13th/14th century glass can be re-dated to the early 14th century to ally with the third building phase dated 1310-1325. This is corroborated by three of the four parallels dating to the early 14th century.

- The third glazing episode, dated by way of the parallels to the mid-14th century can be seen to correspond with the use of the fabric fund in 1333-38. It is known that immediately prior to this date the abbey was in severe debt after the completion of phase three of the church construction (Atkinson, 1894)

- In the 15th century the church was completed and the Great West Window in the Perpendicular in style was inserted in the final major construction work at the abbey; the dating for the glass to the early to mid-15th century coincides with this construction work although the dating using the parallels remains unchanged

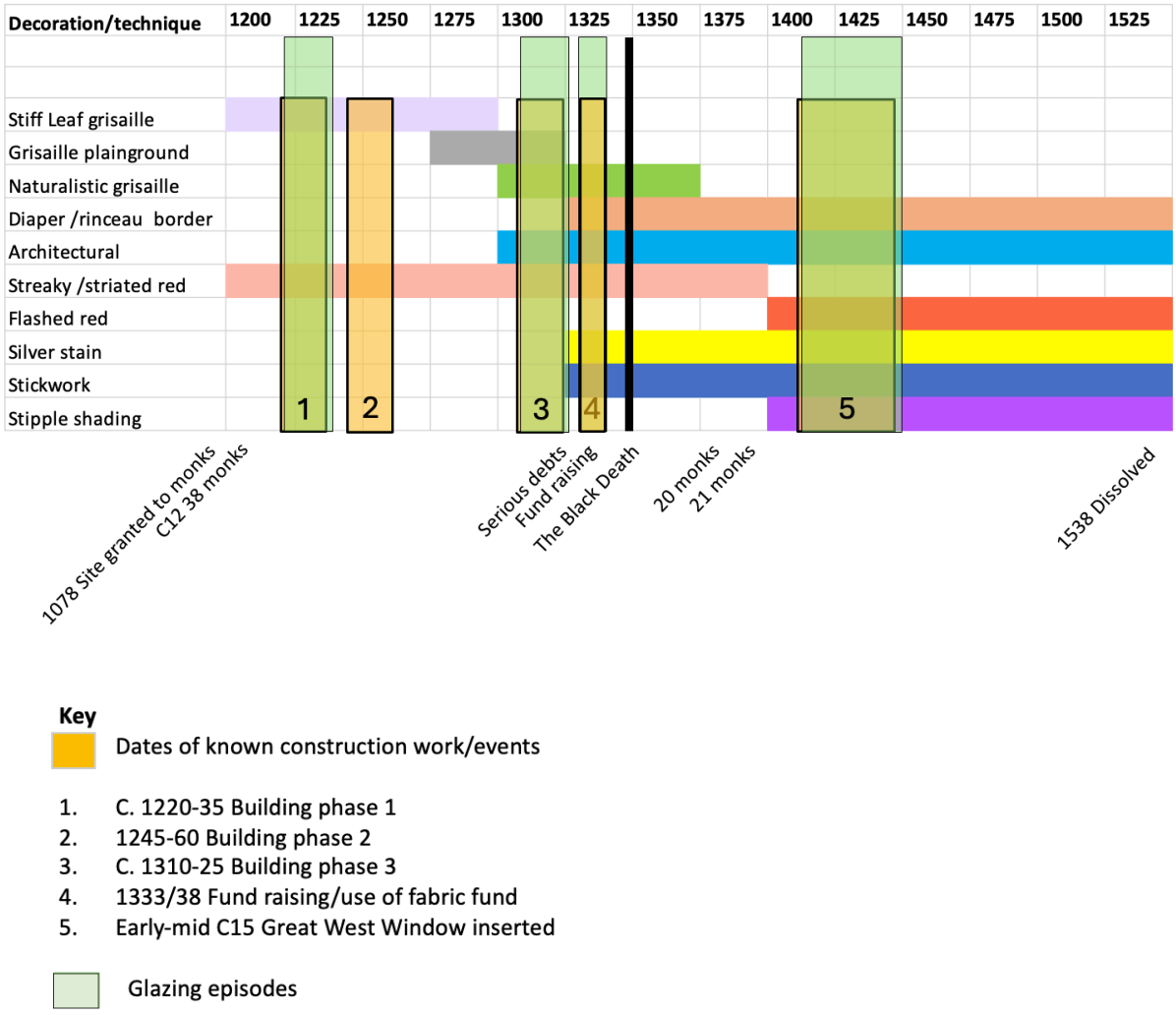


Figure 7.67 Whitby Evidence Informed Dating Framework

The new dating of the glasses from Whitby using EIDF is presented in table 7.28.

Table 7.27 Revised dating of the glasses from Whitby using EIDF

Date range	No. samples	Stylistic dating
C13	10	1220-35
C14a	1	1310-25
C14b	9	1333-38
C15	9	Early to mid C15

7.8.3 Technical results for Whitby

Many of the earlier glasses are severely weathered with an opaque crust and flaking. Three 13th century glasses are pitted (W1, W31, W6,) and W8 from the C14a group has pitting and a lead shadow. This demonstrates weathering while installed. The poor condition of the earlier glasses is in contrast to most of the 14th and 15th century glasses, 12 of which are uncorroded or have only minor corrosion. Over half of the glasses, predominantly from the 14th century retain at least one grozed edge and one 15th century sample (W16) has four grozed edges and may have formed a sub-square shape. Other original shapes are rectangular border quarries and a diamond apex.

The glasses demonstrate decreasing thicknesses through the date ranges, for example, the 13th century average is 3.5 mm, the 14th century average is 2.6 and the average for the 15th century groups is 2.3 mm. There is no evidence for crown production in the sample set but there is one example of broad glass in the 15th century group, demonstrated by way of bubble orientation (W13). As discussed in 2.6.1, only the parallel alignment of long thin bubbles is reliable evidence of broad production, thus, this is the only use of bubble orientation in the project to determine forming process (circled in figure 7.68)

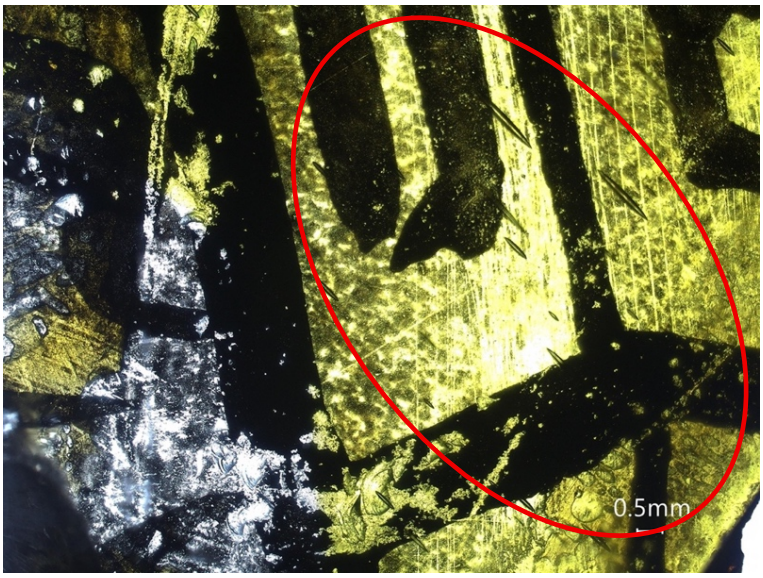


Figure 7.68 W13, parallel alignment of long thin bubbles

There are six coloured samples in the assemblage, two blue (W27, W28) and four red, of which two are flashed (W21, W24) and two are striated (W25, W26). The naturally coloured glasses are pale green, and the three 15th century silver-stained glasses (W13, W14, W20) are colourless. These glasses, in addition to two others from the 15th century (W22, W16) are painted dark brown in contrast to the red-brown paint of the remainder of the painted glasses from all date ranges. W22 and possibly also W20 depict tessellated flooring (and use the same palette as the glasses of the same design from Hyde, e.g. H50). W18 and W20 have evidence of a repair using shellac. There are no reports of repair to this sample post-excavation thus this glass was probably repaired whilst installed.

7.8.4 Compositional results for Whitby

The 13th, 14th and two of the 15th century groups are forest glasses, and the remaining 15th century group is HLLA. The discriminating elements that best show the different groupings for Whitby are potassium, calcium and magnesium.

The scatterplots of potassium oxide (K_2O) vs. calcium oxide (CaO) (figure 7.69) and potassium oxide vs. magnesium oxide (MgO) (figure 7.70) show that there are up to nine compositional groupings, two in the 13th century, four in the 14th century and three in the 15th century. These groupings represent four glazing episodes at the abbey. Figure 7.59 shows that the C15c HLLA group is distinct, with a low level of potassium and high level of calcium. Some of the compositions of the forest glasses overlap, however, showing that there are similar compositions across different date ranges. This is also shown in the PCA bi-plot (Appendix 16). Nonetheless, the compositional groupings of the forest glasses can be determined when plotted by date range (13th, 14th and 15th century) (figures 7.71 to 7.74).

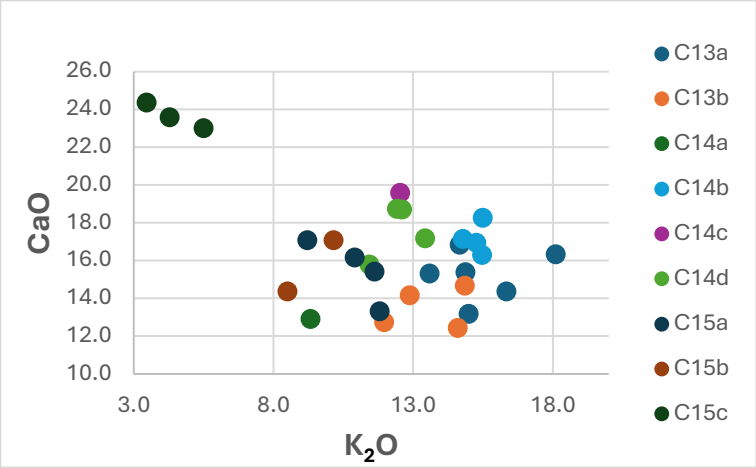


Figure 7.69 Whitby scatterplot for potassium oxide vs. calcium oxide

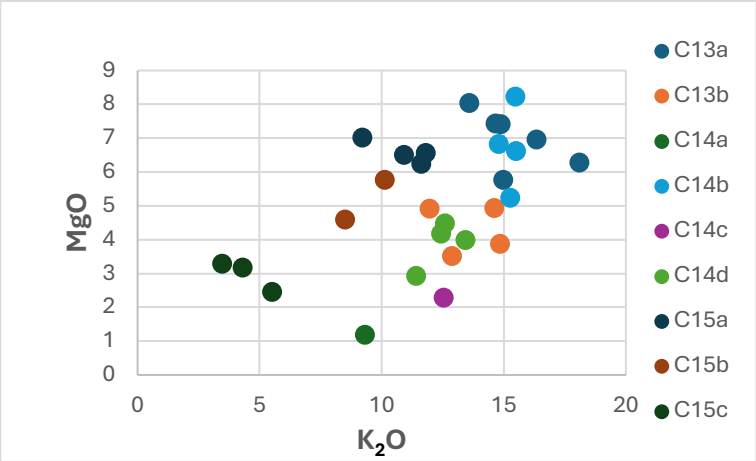


Figure 7.70 Whitby scatterplot for potassium oxide vs. magnesium oxide

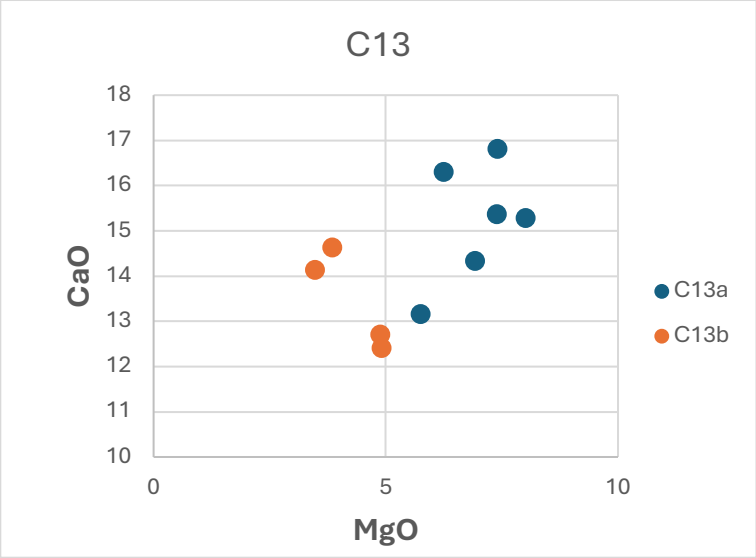


Figure 7.71 Whitby scatterplot for magnesium oxide vs. calcium oxide

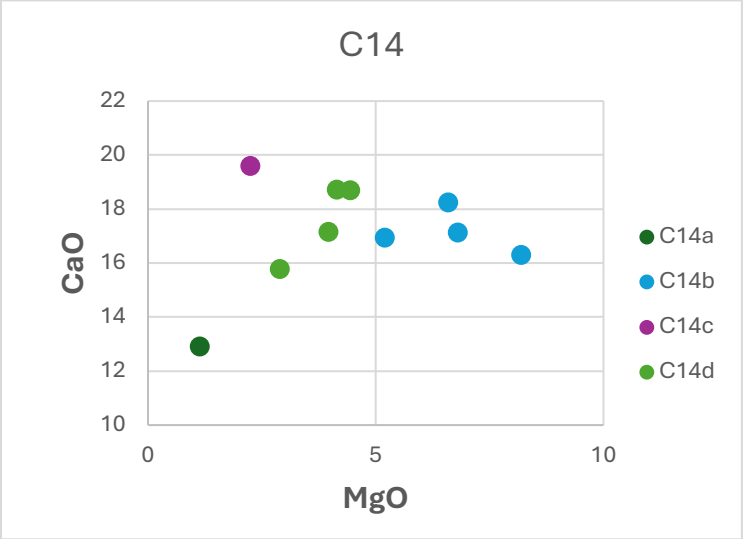


Figure 7.72 Whitby scatterplot for magnesium oxide vs. calcium oxide

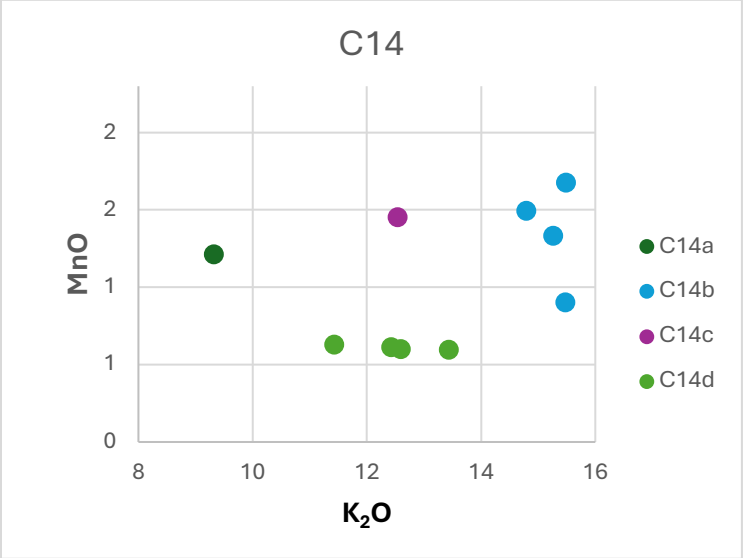


Figure 7.73 Whitby scatterplot for potassium oxide vs. manganese oxide

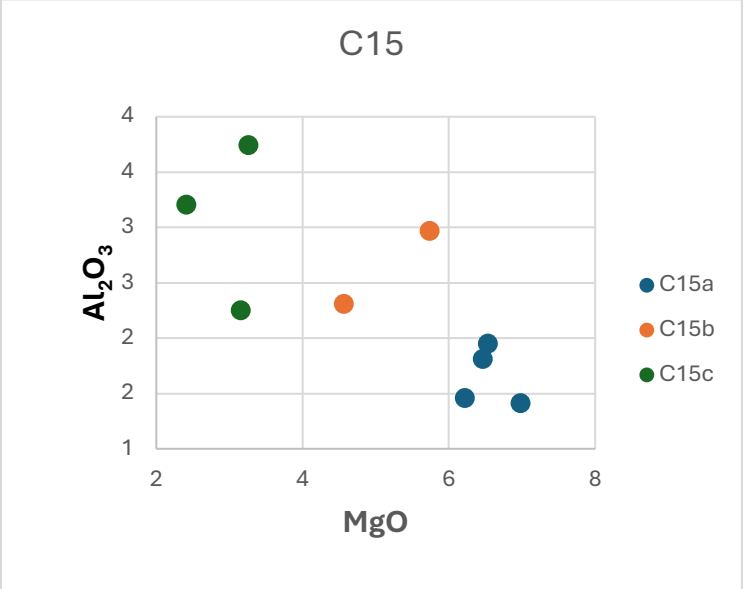


Figure 7.74 Whitby scatterplot for magnesium oxide vs aluminium oxide

7.8.5 The main compositional points from the chemical analysis

The main compositional points for the groupings from all date ranges are presented (table 7.29). Some sulphur values are skewed because of four samples from C13b, C14d, C15b and C15c with high levels of sulphur. The groups are marked with an asterisk against each value.

Table 7.28 Average wt% of main discriminating oxides with standard deviation (SD) for Whitby. CS = no. of coloured samples

Group	No	K_2O	Na_2O	Cl	MgO	CaO	Fe_2O_3	MnO	Al_2O_3	SrO	SO_3	SiO_2	P_2O_5	CaO: K_2O	CS
C13a	**6**	**15.44**	**1.69**	**0.29**	**6.96**	**15.20**	**1.01**	**1.63**	**1.97**	**0.10**	**0.10**	**49.72**	**5.12**	**1.0**	**1**
SD		1.58	0.43	0.10	0.83	1.32	0.33	0.18	0.62	0.02	0.09	2.34	0.41	0.12	
C13b	**4**	**13.59**	**1.12**	**0.36**	**4.29**	**13.46**	**1.04**	**1.14**	**2.18**	**0.07**	**0.87 ***	**56.36**	**4.97**	**1.0**	**0**
SD		1.38	0.33	0.17	0.73	1.08	0.42	0.44	0.48	0.02	0.92	1.15	1.13	0.11	
C14a	**1**	**9.33**	**0.85**	**0.28**	**1.16**	**12.88**	**1.00**	**1.21**	**4.04**	**0.12**	**0.27**	**60.49**	**7.76**	**1.4**	**0**
C14b	**4**	**15.27**	**1.51**	**0.23**	**6.71**	**17.13**	**1.08**	**1.35**	**2.26**	**0.11**	**0.12**	**48.50**	**5.05**	**1.1**	**2**
SD		2.67	0.45	0.03	2.70	2.03	0.29	0.29	0.92	0.03	0.12	5.67	1.27	0.12	
C14c	**1**	**12.56**	**0.97**	**0.89**	**2.26**	**19.56**	**1.79**	**1.45**	**2.95**	**0.13**	**0.07**	**43.94**	**10.4**	**1.6**	**0**
C14d	**4**	**12.4**	**1.09**	**0.24**	**3.88**	**17.57**	**1.09**	**0.61**	**2.05**	**0.06**	**0.57 ***	**55.82**	**4.00**	**1.4**	**1**
SD		0.71	0.19	0.28	0.93	1.51	0.40	0.38	0.82	0.04	0.51	5.55	2.93	0.11	
C15a	**4**	**10.9**	**1.96**	**0.26**	**6.56**	**15.45**	**0.79**	**1.49**	**1.65**	**0.07**	**0.23**	**56.57**	**3.61**	**1.4**	**0**
SD		1.18	0.35	0.11	0.32	1.60	0.14	0.31	0.26	0.01	0.21	1.15	0.51	0.31	
C15b	**2**	**9.34**	**1.15**	**0.06**	**5.16**	**15.67**	**0.91**	**1.71**	**2.63**	**0.08**	**1.33 ***	**60.68**	**4.59**	**1.72**	**2**
SD		1.16	0.34	0.08	0.83	1.92	0.33	0.30	0.47	0.00	1.29	4.94	0.77	0.00	
C15c	**3**	**4.43**	**2.25**	**0.25**	**2.95**	**23.61**	**1.31**	**0.73**	**3.06**	**0.12**	**0.77 ***	**57.15**	**2.94**	**5.5**	**0**
SD		1.03	1.16	0.17	0.46	0.69	0.60	0.30	0.75	0.05	0.38	2.16	0.07	1.42	

C13a

Table 7.29 shows that the glasses have high levels of potassium, magnesium, phosphorus and manganese and a low level of silicon. The one coloured glass is blue (see figure 7.30).

C13b

As shown in table 7.29, there are four samples with a slightly higher amount of silicon than is usually found in a 13th century composition (e.g. Wedepohl, 1997, p. 250). This may be from the surface enrichment due to corrosion. W2 has an elevated level of sulphur (2.14%), possibly derived from gypsum (calcium sulphate dihydrate) on the surface from weathering.

C14a

Table 7.29 shows that the single sample has high levels of silicon and aluminium, and low levels of potassium, magnesium, calcium and phosphorus. The Ca:K ratio demonstrates that the composition is higher in calcium than potassium.

C14b

There are high levels of potassium, magnesium, calcium and phosphorus in this group, as shown in table 7.29, and silicon is very low; the composition is similar to C13a. There are two coloured samples, W25 and W26, which are both streaky red and based on their close chemical composition are probably from the same sheet, see table 7.30 below.

C14c

The single sample, as shown in table 7.29 has high calcium, phosphorus and iron, and low silica and magnesium. The Ca:K ratio demonstrates a calcium-rich composition. Of note is the high amount of copper, zinc and lead in the sample that suggests that coloured cullet was added to the batch, perhaps as window glass with the lead came still attached.

C14d

The group of four glasses is characterised by very high calcium with low potassium and manganese (table 7.29). W18 contains a high level of sulphur (1.11%) and may be contaminated with gypsum. There is one coloured glass, W28, which is blue, see table 7.30 below.

C15a

C15a comprises four samples of which three are silver-stained. Table 7.29 shows that the glasses have high levels of magnesium and manganese, and low levels of potassium, iron and aluminium. The glasses are forest type.

C15b

The two flashed red samples, as shown in table 7.29 have high levels of manganese and low levels of potassium and sodium. W24 has a high level of sulphur (2.24%) and may be contaminated with gypsum.

C15c

As shown in table 7.29, the C15b glasses are HLLA with very high calcium, and very low potassium, magnesium, manganese and phosphorus. W30 has a high level of sulphur (1.16%) probably due to gypsum formation on the surface of the glass.

7.8.6 Coloured glasses

The following table 7.31 shows the colouring method for each of the coloured glasses from Whitby. There are six coloured fragments of only two different colours, blue and red. The 13th century and 14th century blue glasses (W7, W28) are coloured using trace amounts of cobalt and in addition contain copper, zinc and lead, which is probably derived from brass filings

together with a cobalt source. There are two types of red glass: striated (W25, W26) and flashed (W21, W24), although the red coloured parts were not analysed. Nonetheless, both types are able to inform on dating: the striated (Kunicki-Goldfinger type A) dates from the 12th century to the end of the 14th century and flashed red (Kunicki-Goldfinger type B) dates from the end of the 14th century (Kunicki-Goldfinger et al, 2014).

Table 7.29 The colouring method for each of the coloured glasses from Whitby

Colour	Colourant	Samples	Dated group	Information
Blue	CoO (0.16%)	W7	C13a	CuO (0.31%), ZnO (0.32%), Fe_2O_3 (1.79%) from the Co ore
	CoO (0.06%)	W28	C14c	Cu (0.10%), Zn (0.21%), Fe_2O_3 (1.52%)
Striated red	Fe_2O_3 (1.45%)	W25	C14a	CuO (0.12%), ZnO (0.10%)
	Fe_2O_3 (1.26%)	W26		CuO (0.17%), ZnO (0.08%), Fe_2O_3 (1.26%)
Flashed red	Red part not analysed	W21	C15a	
		W24		

7.8.7 Cullet

There is evidence for the use of coloured cullet by way of small amounts of colourants present in the composition of some of the non-coloured glasses from the 13th, 14th and 15th centuries. Trace amounts of cobalt are found in one third of the 13th century non-coloured glasses, two of the 14th century samples (W7, W19) and three of the 15th century samples (W16, W13, W33). There are no samples that contain copper.

7.8.8 Summary of analytical results for Whitby

The first glazing episode dates to 1220-35 when phase one of the church construction was undertaken. The glasses are predominantly pale green and decorated with stiff leaf grisaille motifs, and one glass is blue and undecorated. The glasses were probably part of a simple grisaille scheme with coloured quarries interspersed around the panel. The fragments are thick, yet no forming technique is discernible.

The second glazing episode is represented by a single fragment with a forest glass composition that is dated to 1310-25 and phase three of the construction of the church. The glass is naturally coloured pale green and decorated with a naturalistic grisaille motif. It is difficult to speculate on the window design based on a single fragment, but grisaille schemes comprising natural forms set within interlacing trellis or strapwork were common in the early 14th century, for example at Merton College, Oxford. There is no evidence of forming technique.

The third glazing scheme represented by nine fragments is dated 1333-38 when the fabric fund was used to complete the glazing for phase three. There are three groups with a forest glass composition, one of which is calcium-rich. There is no evidence of forming technique for any of the compositional group in this date range. The bulk of the glasses are naturally coloured pale green, and these are decorated with motifs that represent a parsimonious grisaille scheme of decoration.

The fourth glazing scheme is represented by nine glasses that are dated to the early to mid-15th century when the west end of the church was completed and the replacement Great West Window inserted. The glasses are possibly from this window. There are three compositional groups, C15a and C15b are forest types and C15c has an HLLA composition. Glasses in the C15a group are pale green and silver-stained (excluding W16); the glasses from C15b are flashed red and undecorated, and the C15c glasses are pale green, one decorated and two plain. The fragments from all groups are predominantly thin, and C15a glasses have evidence of broad-production by way of parallel bubbles.

The west window in a monastic church was a significant focal point and typical decoration included images of saints and historical figures in architectural settings. Although there are no figural fragments present from this date range, there are architectural and floral motifs that may have made up the background to a figural scene.

7.9 Summary of analytical results for all sites

The results from the stylistic analyses of the glasses from these seven sites show that the earliest fragments are dated to the late 12th century and the latest to the early 16th century. By combining the dates of the glasses from the stylistic analysis with the chemical data from the micro-XRF analysis, groupings can be seen and the glazing episodes at each site can be determined. The compositional data also shows that forest glass was used throughout the study period with a calcium-rich forest glass also used during the 14th century, and from the early 15th century most of the glasses have an HLLA composition. The data shows how the glasses were coloured, that some of the 15th century HLLA glasses are manganese-rich, and that the addition of coloured cullet is evident throughout the study period - although prevalent in the 14th century, and across all sites. The results of the technical analysis show the physical qualities of the glasses in terms of the original quarry shapes and the state of preservation, glass thickness and finesse of manufacture, and evidence of how some of the window glasses were formed either by the broad of the crown method. It is shown that over time changes are seen in the range of colours used, and an increasing finesse is evident by the production of thinner and more colourless glass that generally corresponds with the HLLA recipe and broad production.

The following chapter (eight) presents an appraisal of the selected regional compositions from production sites in England and continental Europe, and a tentative provenance to a broad region or country is assigned for each group of glasses in the study.

Chapter 8

8. Provenance

8.1 Introduction

Knowledge about the source of the window glass is an essential aspect of the study into the use of window glass at high status sites - patterns of use can be observed and the reasons for consumption choices can be examined. Provenance is determined by cross-matching the compositions of the research material with the published regional data. This is done using scatterplots of the elements potassium vs. calcium and PCA bi-plots. Potassium and calcium are both good at discriminating different glass groups through time. A scatterplot of sodium vs. silicon is also used at Louth Park. The process of assigning provenance, albeit tentatively, also involves referring to the data sets from the chemical analysis of the study glasses and comparing with the data from the published and unpublished regional compositions for a more nuanced comparison. The scatterplots look at the ratios of two elements together, and the PCA accounts for an average of 62% of the variability in the data, thus a multi-method approach was used.

This chapter reports the provenance of each compositional grouping in each broad date range, between the 12th and 16th centuries, for each site. In the absence of documentary sources relating directly to the supply of glass to a particular abbey, provenance is suggested tentatively, based on the currently available, limited sets of analyses previously performed. The regional data used in this chapter has been discussed and is presented in chapter two, sections 2.11 to 2.16, and table 2.6 and the full data set from this Doctoral study is presented in the Appendices 26-32. Data from the following publications of glass analysed from France, Germany and England is used in the tables and figures throughout this chapter: Barrera and Velde, 1989 (France: FR E); Gratuze, unpublished (France: FR A1, FR B, FR C, FR E1); Wedepohl, 1996 (Germany: GER B2); Wedepohl, 1997 (Germany: GER A, GER B1, GER C); Mortimer, 1997, Freestone et l, 2010, Meek, 2011, Paynter in preparation (Staffordshire: ENG ST); Merchant, 1998, Welham, 2001, Dungworth and Paynter, 2010, Meek, 2012 (the Weald: ENG TW).

8.2 Alcester

Figure 8.1 shows that the 37 glasses from Alcester are split into four compositional groups dated from the 13th to the 16th century (see section 7.2.5); each group is provenanced to a different French source, described below. See figures 8.2 and 8.3 for scatterplot of potassium vs. calcium and the PCA results.

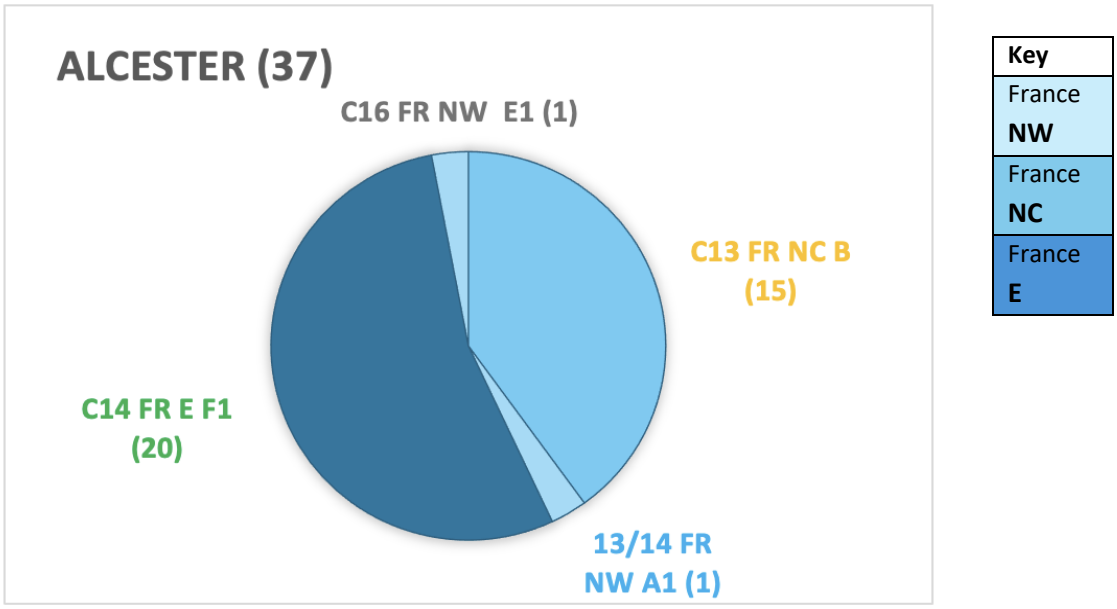


Figure 8.1 Pie chart showing a tentative provenance of 37 glasses from Alcester, dated from 13th to the 16th century

- The composition of the 13th century matches with that of the north-central area of France (FR B). The compositions are similar in the levels of potassium and an average Ca:K ratio of 1.0 (ALC C13) and 0.9 (FR B)

- The 13th/14th century glass matches well with the compositions from Normandy (FR A1) using sodium, magnesium, silicon and aluminium

- The 14th century group is tentatively provenanced to eastern France (FR F1). The composition from this production area and the samples in the 14th century group have similar levels of calcium, potassium, silicon and manganese. The scatterplot of potassium vs. calcium (figures 8.2) shows that the group also aligns with the English data points, but reference to the full data set (Appendix 26) shows that these samples have lower levels of magnesium and manganese than are typical for an English composition

- The 16th century glass is provenanced to northwest France (FR E1) as the compositions are comparable for silicon, potassium, aluminium and phosphorus. The composition of the Alcester glass has many similarities with an English composition (figures 8.2 and 8.3); however, the levels of manganese, magnesium and aluminium preclude an English provenance

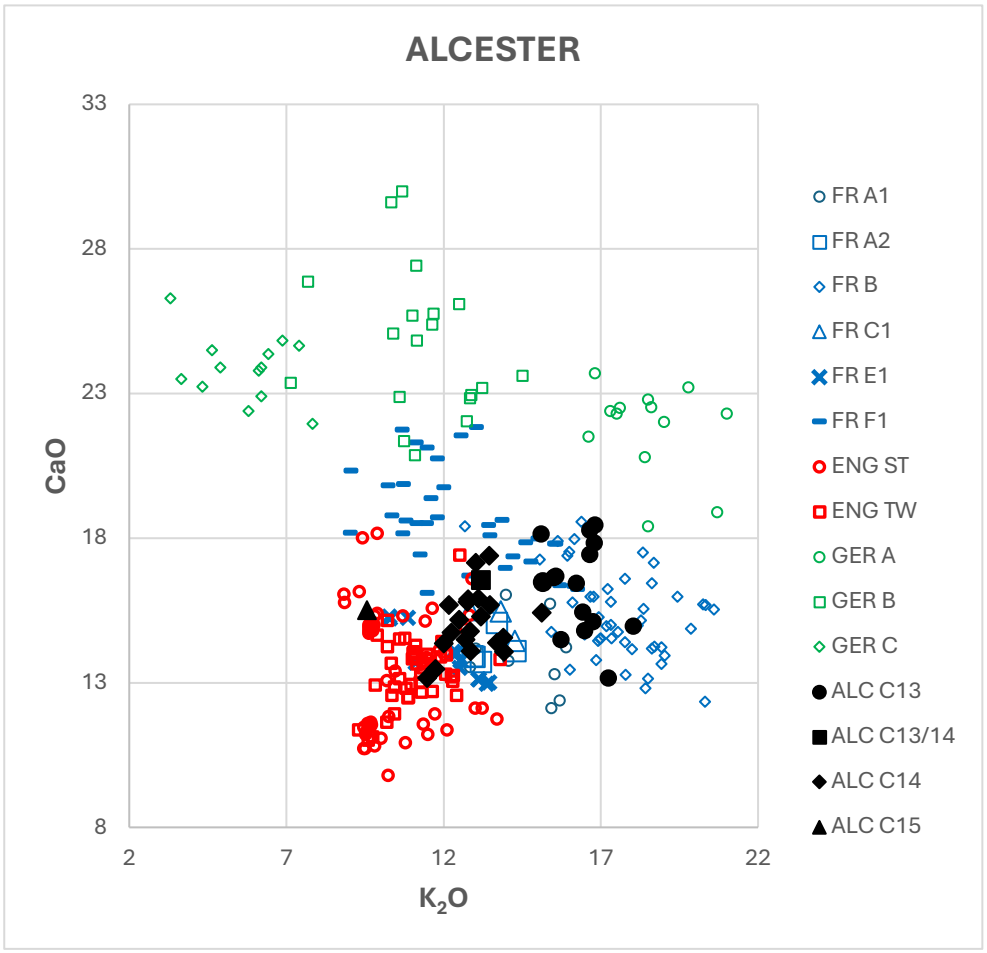


Figure 8.2 Potassium oxide vs. calcium oxide

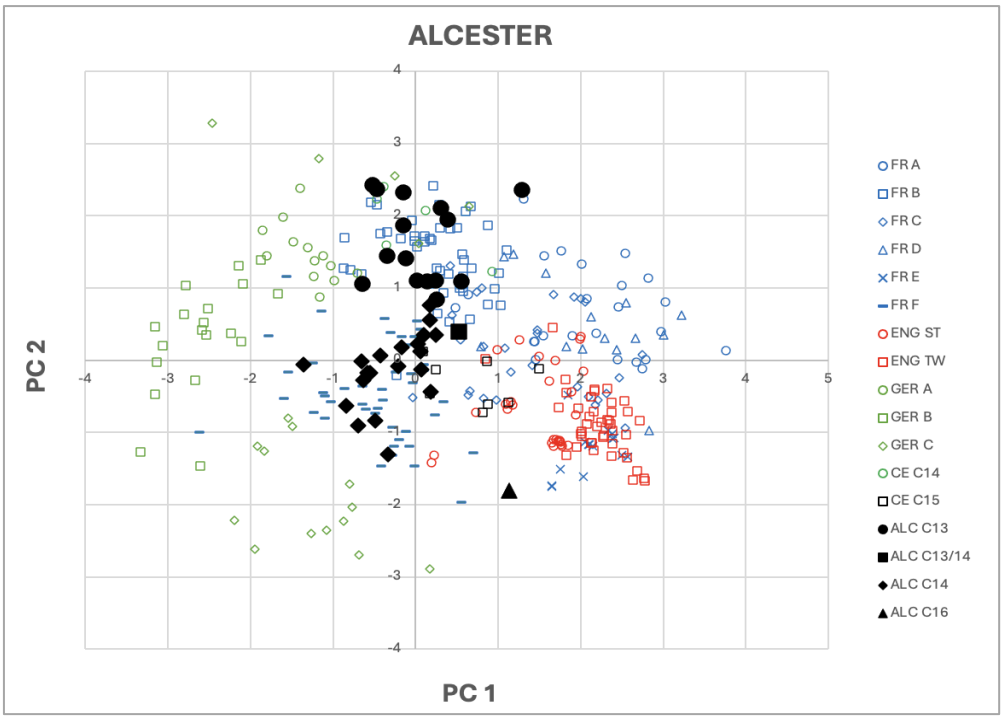


Figure 8.3 Alcester PC1 and PC2

8.3 Bardney

Figure 8.4 shows that there are 23 glasses from Bardney dated from the 12th to the 15th century with a variety of origins, described below. See figures 8.5 and 8.6 for scatterplot of potassium vs. calcium and PCA results.

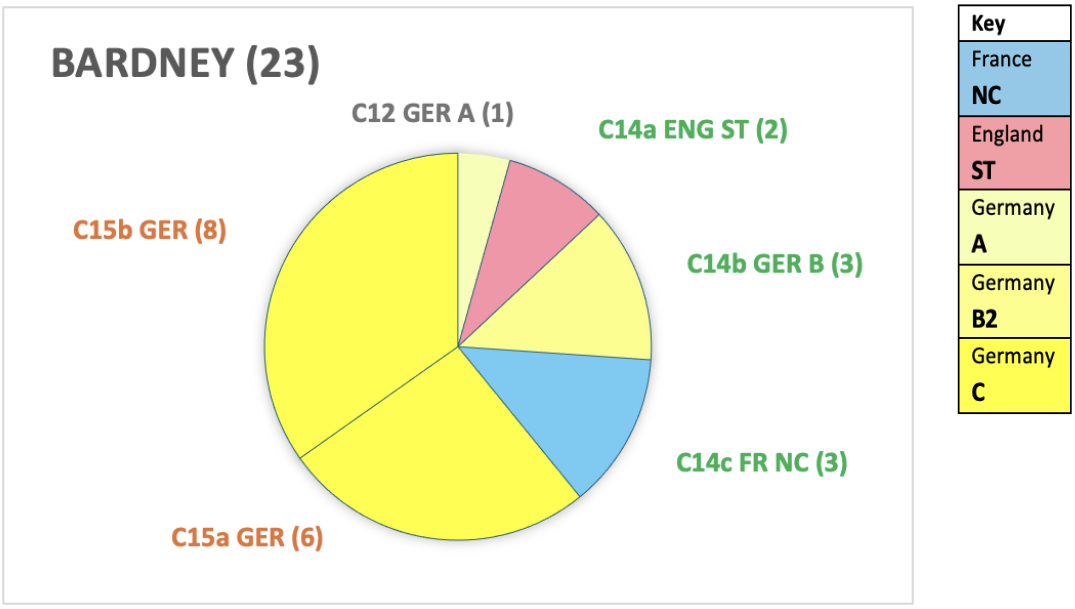


Figure 8.4 Pie chart showing a tentative provenance of 23 glasses from Bardney, dated from 12th to the 15th century

- The late 12th century glass is tentatively provenanced to Germany (GER A) as there are comparable levels of calcium, potassium, manganese and silicon

There are three groups of 14th century glasses provenanced to different production areas:

- The composition of the C14a group is similar to that of Staffordshire (ENG ST). The sample and source compositions are characterised by high levels of magnesium and manganese and low levels of potassium. As shown in table 8.1, the average composition of C14a compares well with the Staffordshire averages (taken from the regional data, section 2.17). For comparison, the average compositions from 13th and 14th century data sets from northwest France are also shown

Table 8.1 The average composition of C14a compared with the Staffordshire averages, also showing NW France averages

Sample	K2O	Na2O	MgO	CaO	Fe2O3	MnO	Al2O3	SiO2	P2O5	Ca:K
Bard ave	11.00	2.06	6.91	15.66	0.79	1.39	1.88	55.35	3.64	1.5
ST ave	10.78	2.31	7.31	14.69	0.63	1.49	1.74	56.63	3.05	1.4
FR NW A1 ave	14.64	3.43	8.22	13.92	0.55	1.19	1.20	50.70	5.02	1.0
FR NW A3 ave	14.26	3.26	8.83	12.86	0.33	1.31	1.59	52.28	3.69	0.9
FR NW C2 ave	13.81	1.54	4.66	15.35	0.51	0.80	1.44	55.82	3.94	1.1
FR NW D ave	17.11	2.12	5.97	11.76	0.55	0.98	1.19	55.14	3.19	0.7

- The three glasses in C14b match with glasses from Germany (GER B2) (Wedepohl, 1996). They have similar levels of calcium, aluminium, phosphorus and silicon

- The three glasses in C14c match with the north-central area of France (FR B) where the composition has high amounts of potassium

There are two groups of 15th century glasses both of which match Germany (GER C). Both C15a and C15b are HLLA compositions with high levels of calcium and low levels of potassium, and thus similar to the Germany C composition.

- C15a contains high levels of sodium correlating with chlorine suggesting salt (NaCl) was added, in agreement with the Germany C composition

- C15b has elevated levels of manganese correlating with barium, which suggests that a manganese decolourant was added

The two slightly different German C compositions suggest the possibility of two glasshouses from the same area with different workshop practices, one adding salt and one adding manganese decolourant. There is a possibility that the groups of glass were produced at the same glasshouse, however, the groups both contain coloured glasses (C15a, blue and green and C15b, blue and flashed red) therefore the differences in composition may not relate to coloured glass production.

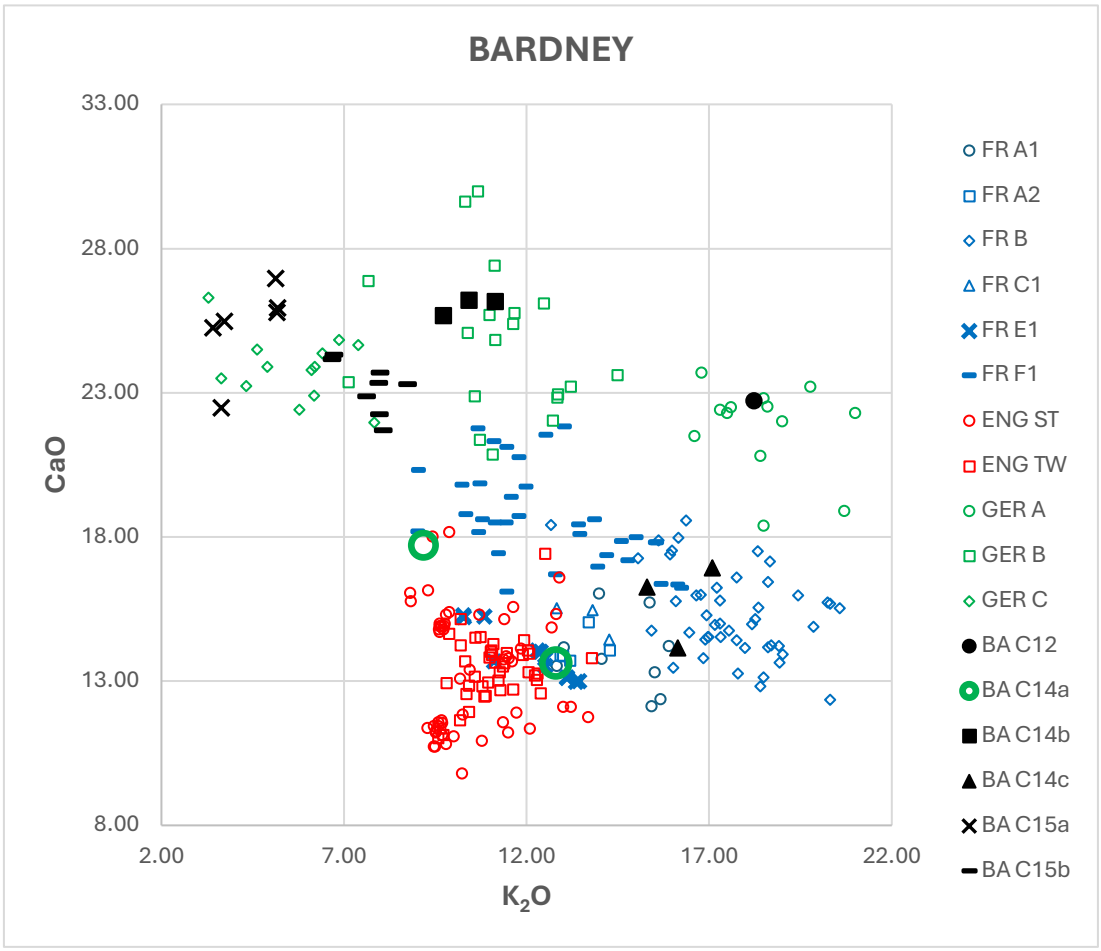


Figure 8.5 Scatterplot of potassium oxide vs. calcium oxide

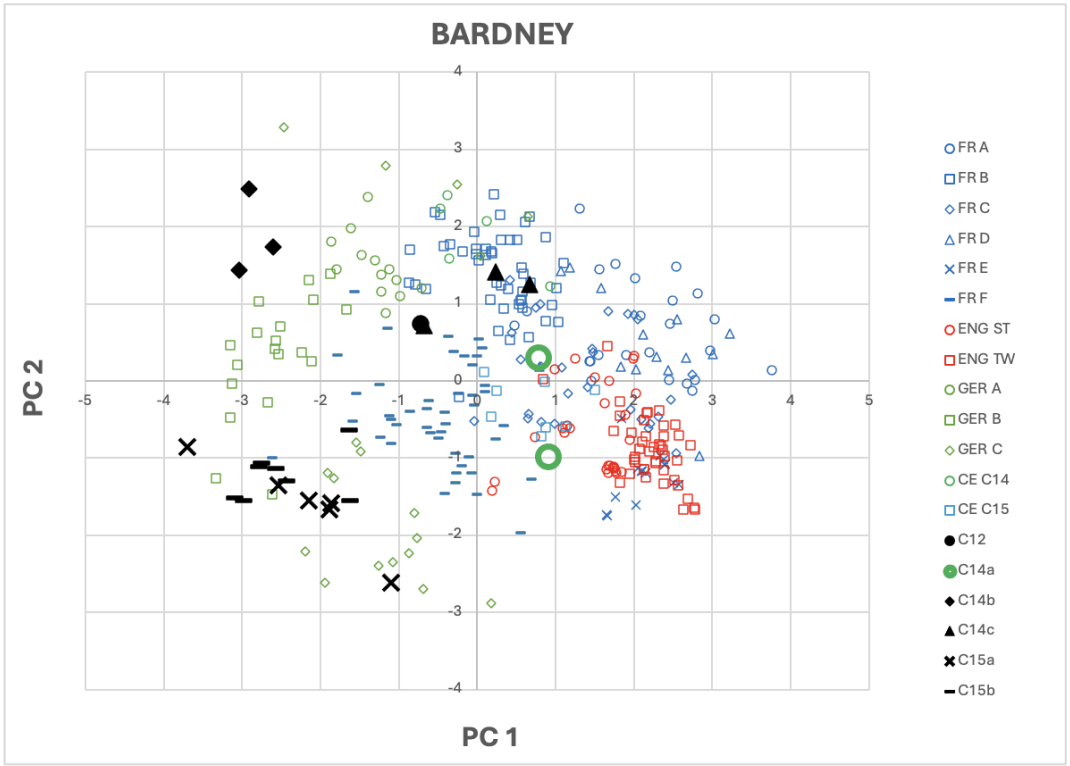


Figure 8.6 PC1 and PC2 for Bardney

8.4 Bordesley

Figure 8.7 shows that the 40 glasses from Bordesley form five compositional groups dated from the 13th to the 15th century, four of which have a tentative French provenance, and a fifth matches with a Staffordshire composition. These are described below; see figures 8.8 and 8.9 for a scatterplot of potassium vs. calcium and the PCA results showing how the compositions match.

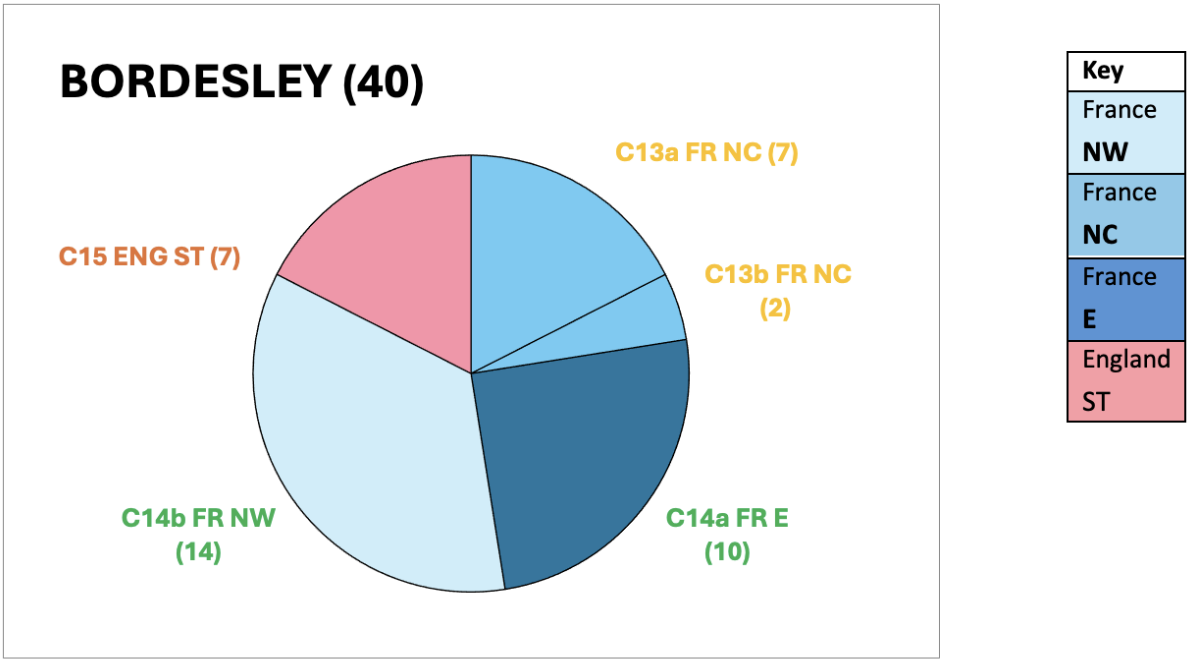


Figure 8.7 Pie chart showing a tentative provenance of 40 glasses from Bordesley, dated from 13th to the 15th century

There are two groups of glasses in the 13th century, dated early (C13a) and late (C13b):

- Both groups can be tentatively provenanced to the same source, the north-central area of France (FR B). The compositions from this region and the samples in the 13th century groups have similar amounts of silicon, aluminium and iron. The Ca:K ratio of France B is 0.9, which compares well with C13b (0.8) but less well with C13a (1.2)

There are two 14th century groups of glasses which can be matched with French sources:

- C14a is comparable with glasses produced in eastern France (FR F1) as both sets of glasses have similar levels of calcium and magnesium and a Ca:K ratio of around 1.3

- C14b has similarities with compositions from the Normandy area of the north-west region of France (FR A1) with comparable calcium, potassium, magnesium, phosphorus and alumina levels. The sample set has a Ca:K ratio of around 1.2 compared with the

Normandy Ca:K ratio of 1.0, showing that there is slightly more calcium present in this sample set by comparison

- There is one group in the 15th century that can be tentatively provenanced to Staffordshire (see figures 8.8 and 8.9) as there are comparable levels of magnesium, manganese and potassium. The compositions match well with the Staffordshire averages (Table 8.2) particularly the lower amount of potassium and high level of manganese. The compositions from the northwest regions of France are also shown in this table to allow a comparison to be made, for example, the higher potassium and lower manganese content of the French compositions.

Table 8.2 The average composition of C15 compared with the Staffordshire averages, also showing NW France averages

Sample	K2O	Na2O	MgO	CaO	Fe2O3	MnO	Al2O3	SiO2	P2O5	Ca:K
Bord ave	10.34	1.21	5.91	16.12	0.55	1.67	1.37	58.75	3.26	1.6
ST ave	10.78	2.31	7.31	14.69	0.63	1.49	1.74	56.63	3.05	1.4
FR NW A1 ave	14.64	3.43	8.22	13.92	0.55	1.19	1.20	50.70	5.02	1.0
FR NW A3 ave	14.26	3.26	8.83	12.86	0.33	1.31	1.59	52.28	3.69	0.9
FR NW C2 ave	13.81	1.54	4.66	15.35	0.51	0.80	1.44	55.82	3.94	1.1
FR NW D ave	17.11	2.12	5.97	11.76	0.55	0.98	1.19	55.14	3.19	0.7

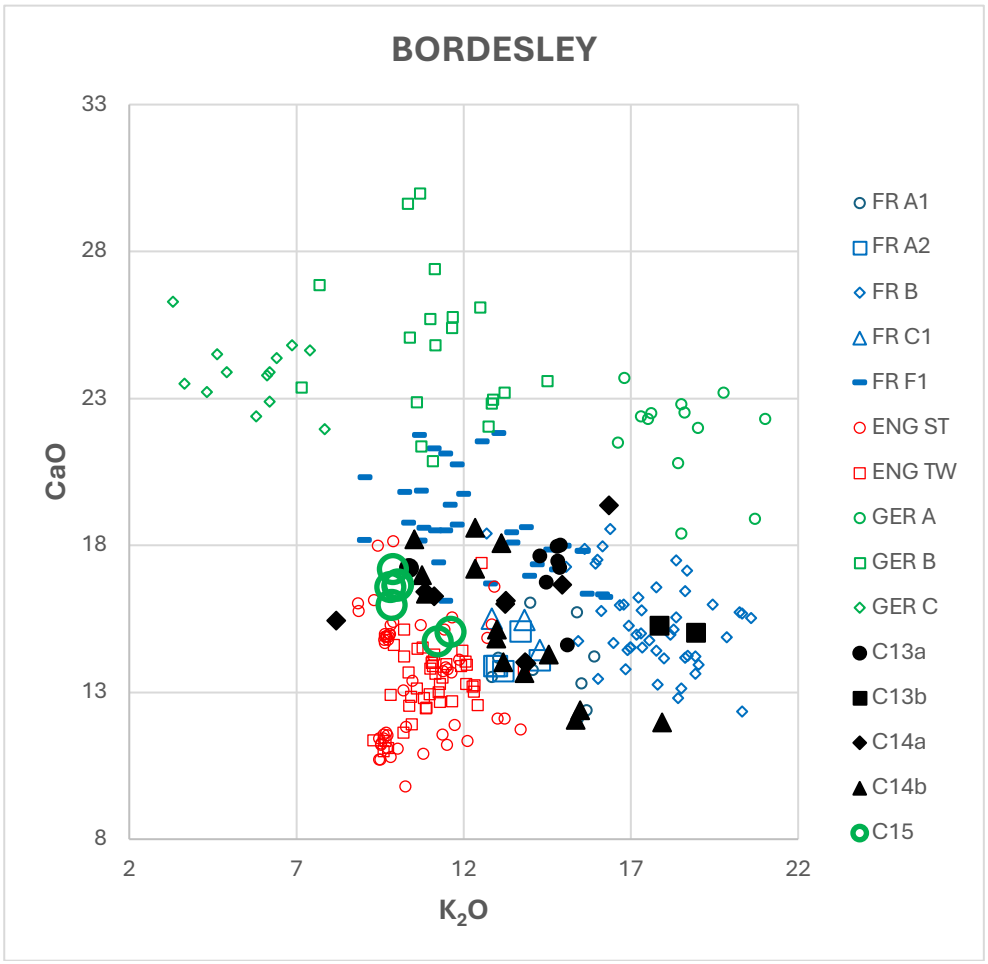


Figure 8.8 Scatterplot of potassium oxide vs. calcium oxide

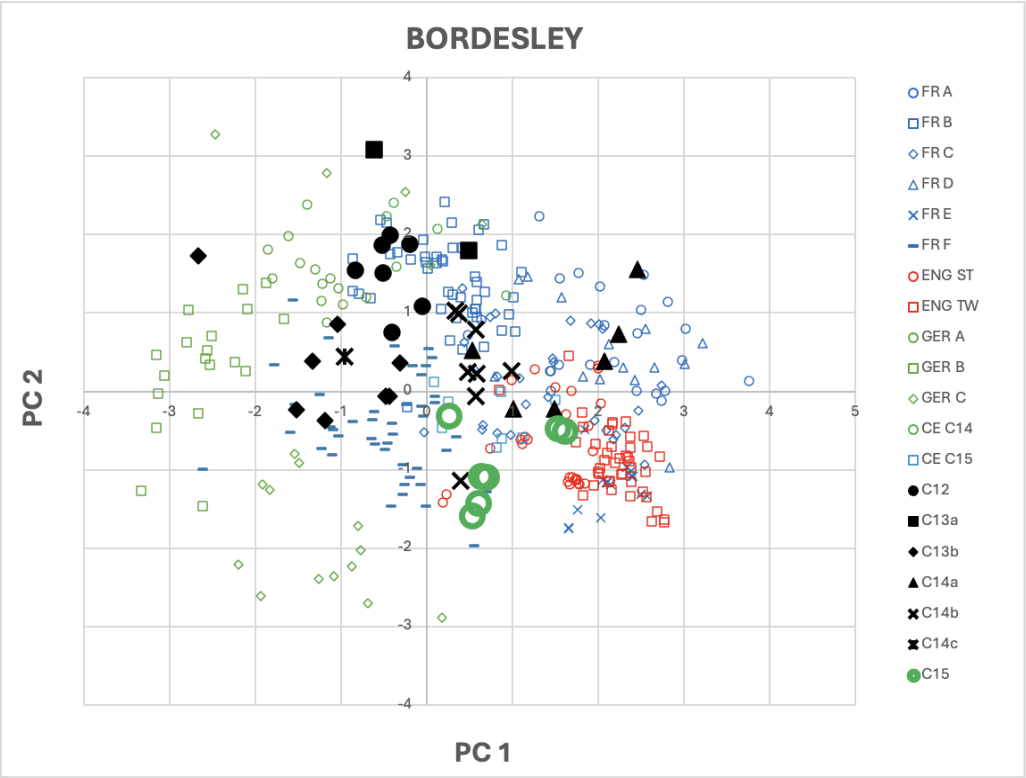


Figure 8.9 PC1 and PC2 bi-plot for Bordesley

8.5 Hyde

Figure 8.10 shows that there are 49 glasses from Hyde that date from the late 12th century to the C15th century. The compositions are varied and there are 10 compositional groups with a range of origins. These are described below. See figures 8.11 and 8.12 for scatterplot of potassium vs. calcium and PCA results.

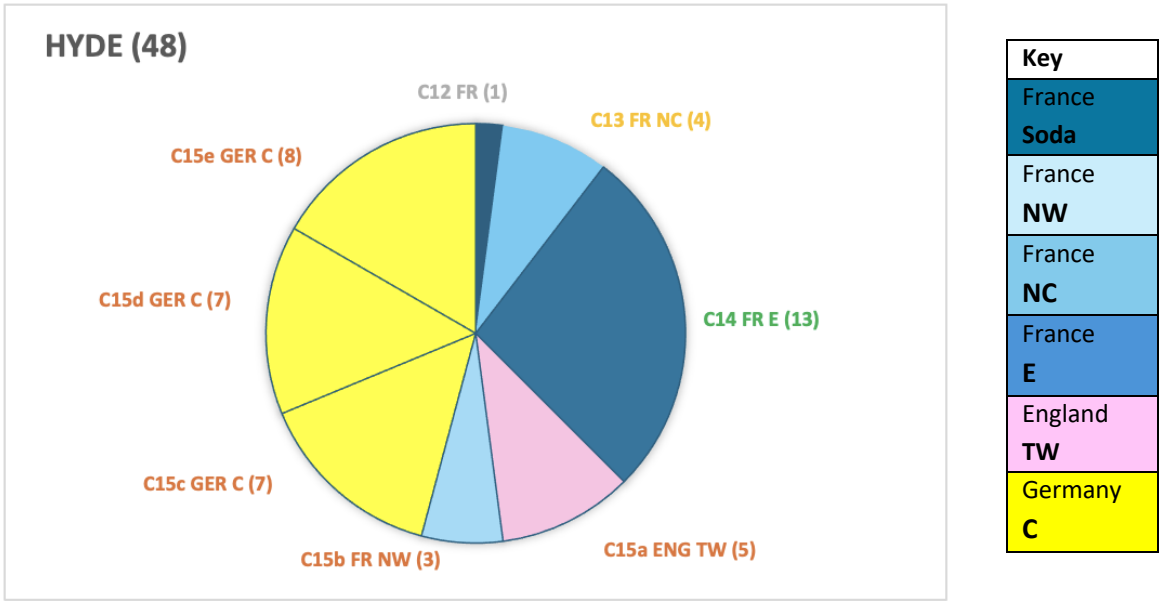


Figure 8.10 Pie chart showing a tentative provenance of 48 glasses from Hyde, dated from 12th to the 15th century

- There is one soda glass from the 12th century that has a comparable composition with glasses found at Jarrow and therefore has a possible French origin (e.g. Freestone and Hughes, 2006)

- The 13th century group comprises four glasses that are tentatively provenanced to the north-central region of France (FR A2) as there are comparable amounts of magnesium, potassium and calcium and a Ca:K ratio of around 1 (Gratuze, unpublished).

- There is one group in the 14th century date range, which has a tentative eastern French provenance (FR F1) with comparable calcium and potassium levels. The average Ca:K ratios are 1.4 (Hyde group) and 1.5 (FR F1).

In the 15th century, the glass is provenanced to three sources:

- C15a is tentatively provenanced to the Weald in England (figures 8.11 and 8.12), where there are similar amounts of potassium and magnesium, and manganese (table 8.3), which is on average lower than the Staffordshire average: 1.22% compared with 1.49% (see table 8.2 above)

Table 8.3 The average composition of C15a compared with the averages from the Weald

Sample	K2O	Na2O	MgO	CaO	Fe2O3	MnO	Al2O3	SiO2	P2O5	Ca:K
Hyde ave	11.24	1.86	5.94	14.40	1.05	1.22	1.81	57.67	3.80	1.3
TW ave	11.11	2.54	6.76	13.38	0.68	1.10	0.95	58.57	3.00	1.2
FR NW A1 ave	14.64	3.43	8.22	13.92	0.55	1.19	1.20	50.70	5.02	1.0
FR NW A3 ave	14.26	3.26	8.83	12.86	0.33	1.31	1.59	52.28	3.69	0.9
FR NW C2 ave	13.81	1.54	4.66	15.35	0.51	0.80	1.44	55.82	3.94	1.1
FR NW D ave	17.11	2.12	5.97	11.76	0.55	0.98	1.19	55.14	3.19	0.7

- C15b has similarities with the compositions from north-western France (FR E1), for example there are comparable amounts of potassium, manganese, iron and aluminium

- C15c, d, e, all have an HLLA composition that match with Germany (GER C). It is possible that three different German glasshouse working at the same time produced these glasses:

    - C15c contains all coloured glasses, flashed red and blue, and the high sodium and correlating chlorine suggests added salt (NaCl) (Wedepohl and Simon, 2010, p. 90)

    - C15d contains all naturally coloured glasses

    - C15e has a composition that may suggest that a manganese decolourant was added

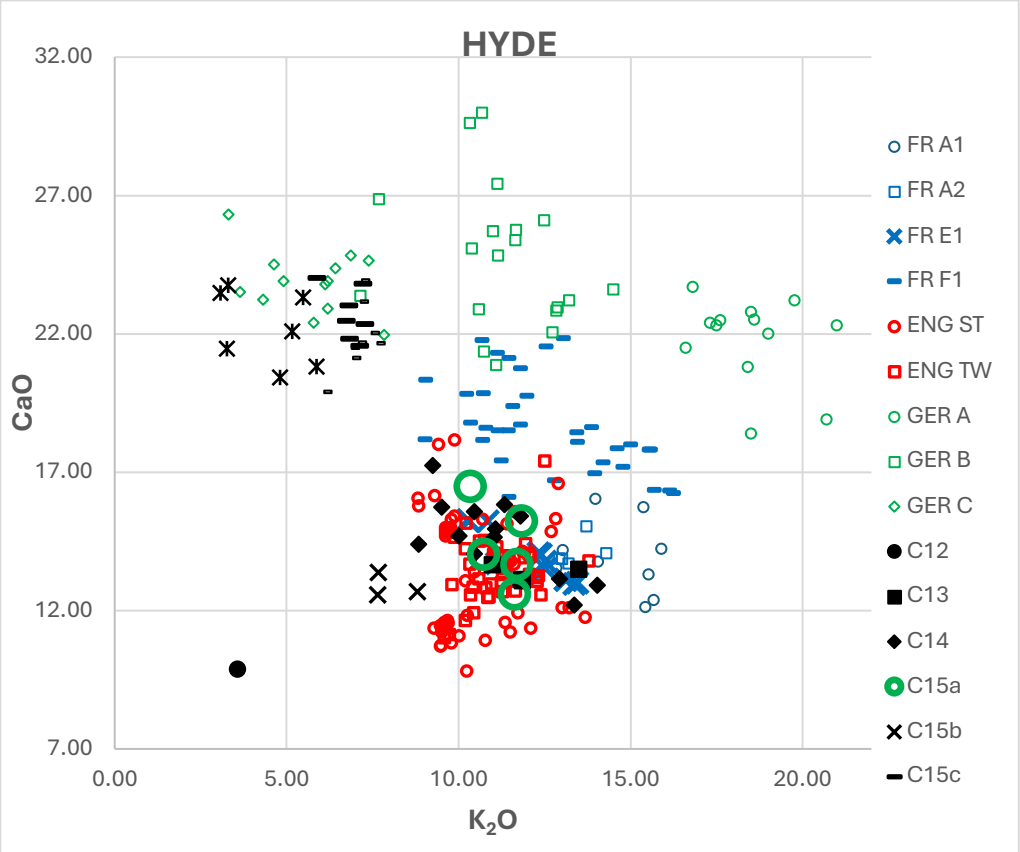


Figure 8.11 Scatterplot of potassium oxide vs. calcium oxide

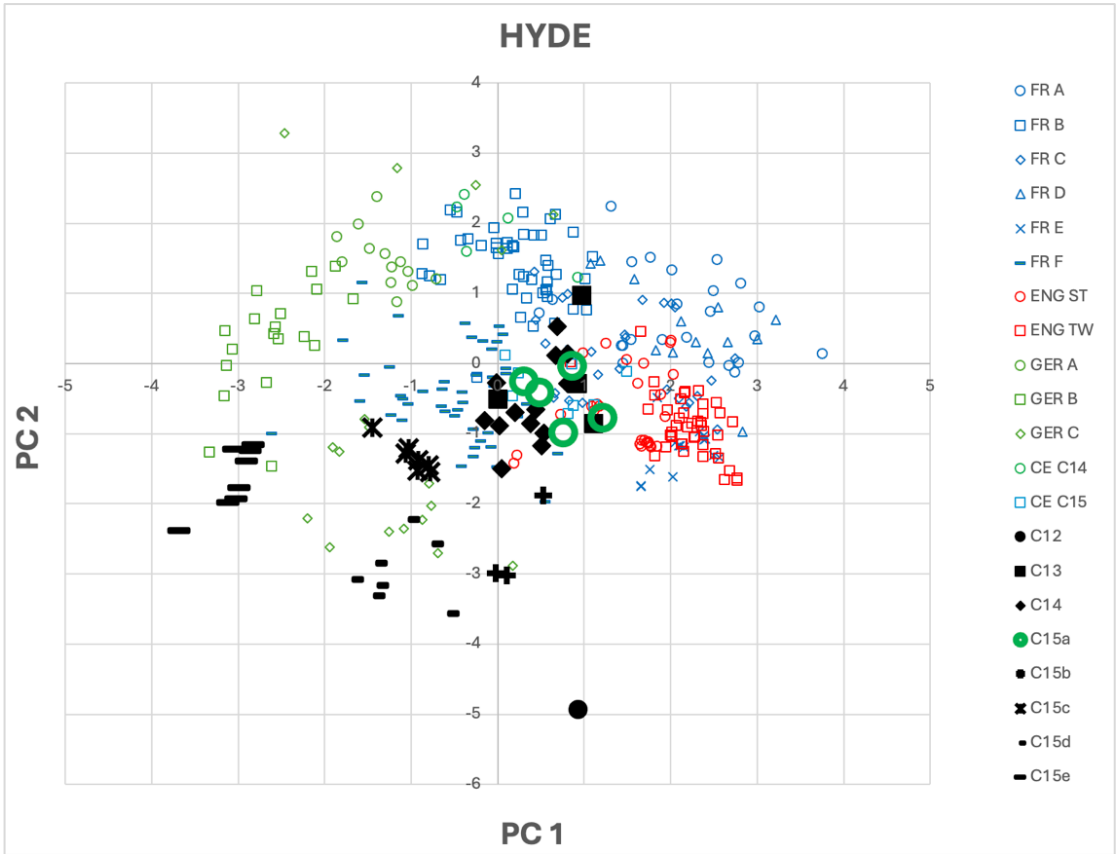


Figure 8.12 PC1 and PC2 bi-plot for Hyde

8.6 Louth Park provenance

Figure 8.13 shows that there are 49 glasses comprising five compositional groups from the 13th to the 15th century. These are described below. See figures 8.15 and 8.16 for scatterplot of potassium vs. calcium and PCA results.

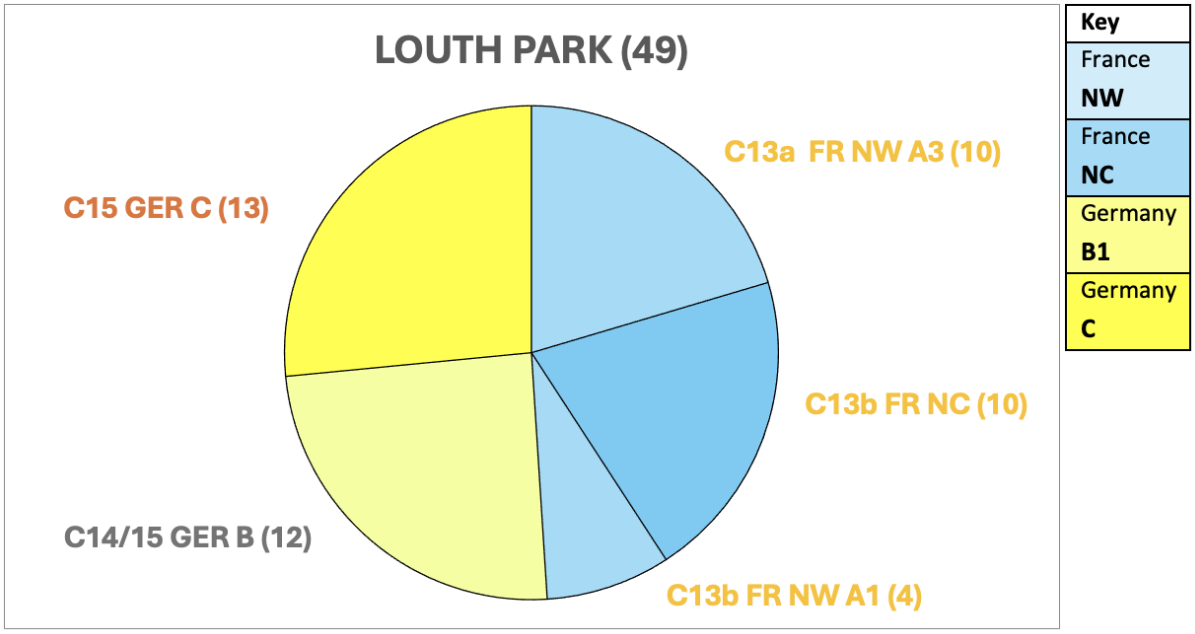


Figure 8.13 Pie chart showing a tentative provenance of 49 glasses from Louth Park, dated from 13th to the 15th century

There are three compositional groups in the 13th century that match with French compositions, and includes two different sources from the northwest region of France:

- On the scatterplot of potassium vs. calcium (figure 8.15 and the PCA bi-plot (figure 8.16) the C13a group appears to match with an English composition. However, reference to the data set (Appendix 30) shows that the C13a group has particularly high levels of sodium, (L1 contains over 6% and L16 over 5%) and lower amounts of silicon. This composition matches with that of Brittany in northwest French (FR A3), which is also dated to the 13th century. The scatterplot of sodium vs. silicon (figure 8.14) shows that 13a plots with Brittany A3. There is a cross-over with the English and Brittany data points at the lower sodium and slightly higher silicon levels

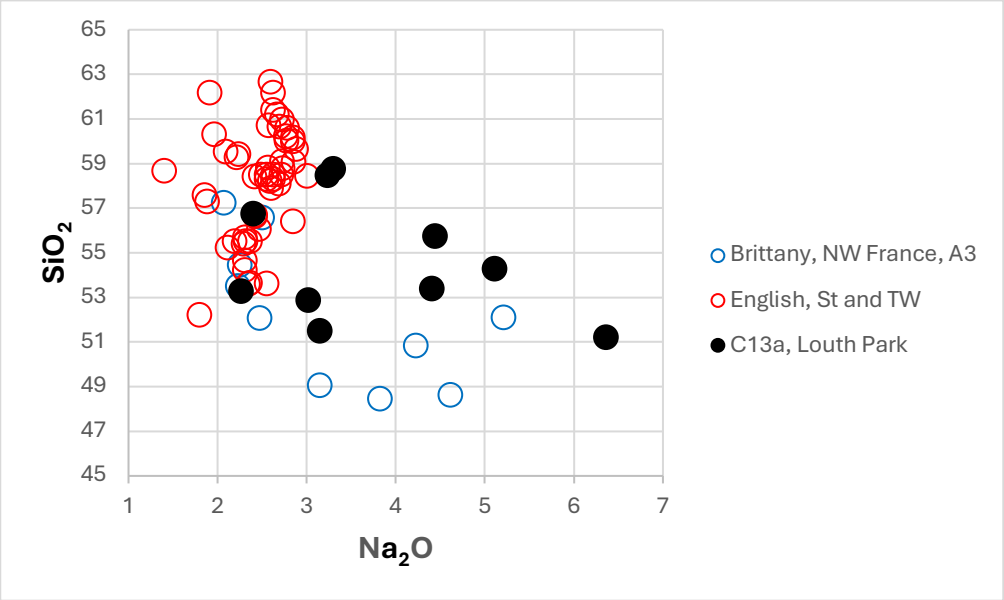


Figure 8.14 Scatterplot of sodium oxide vs. silica dioxide for C13a, showing alignment with Brittany (A3) regional data

- C13b is similar to glasses from the north-central region (FR B) with comparable levels of potassium and calcium

- C13c is likely provenanced to Normandy (FR A1) as both sets of glasses have similar levels of magnesium, potassium, phosphorus, sodium and silicon

The C14/15 group has a similar composition to Germany (GER B1). Both the regional and the Louth Park samples have comparable potassium levels and a high amount of calcium but are not HLLA glasses

There is one group in the 15th century that has a similar composition to Germany (C) (Wedepohl, 1997). The composition for both the regional glasses and the glasses from Louth Park are HLLA and have similar amounts of calcium, potassium and sodium.

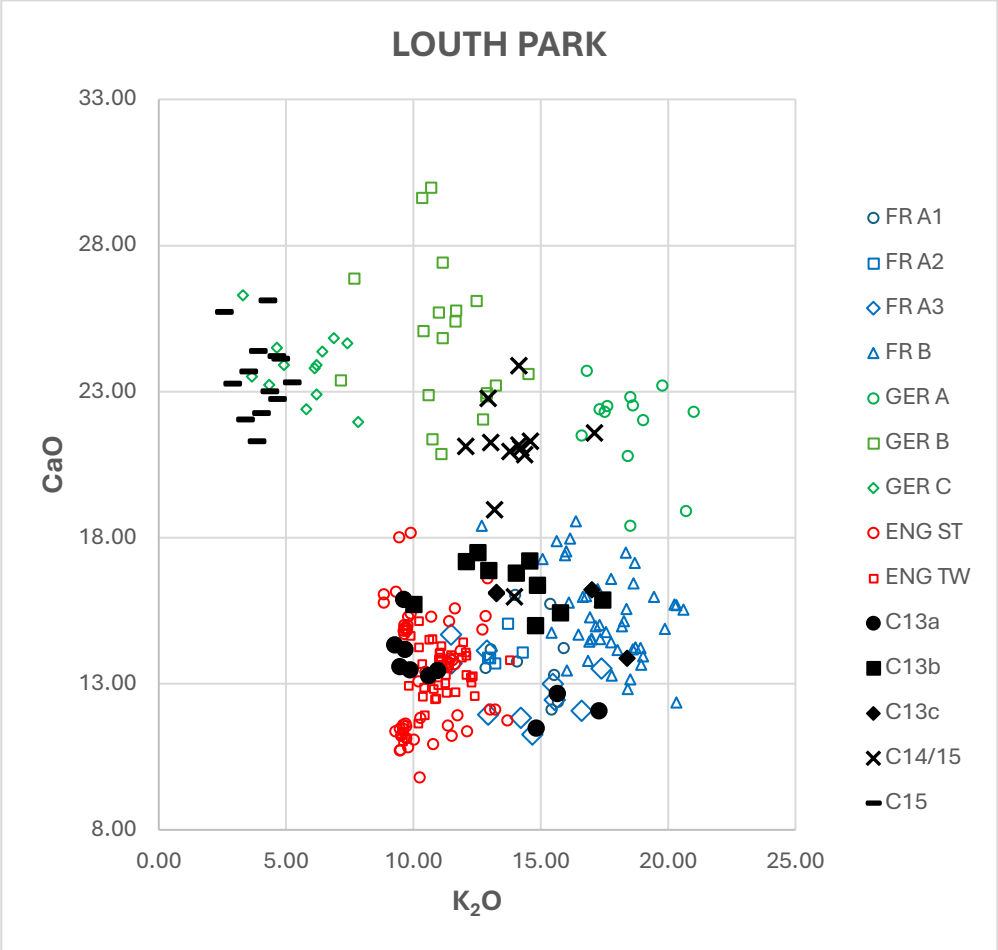


Figure 8.15 Scatterplot of potassium oxide vs. calcium oxide

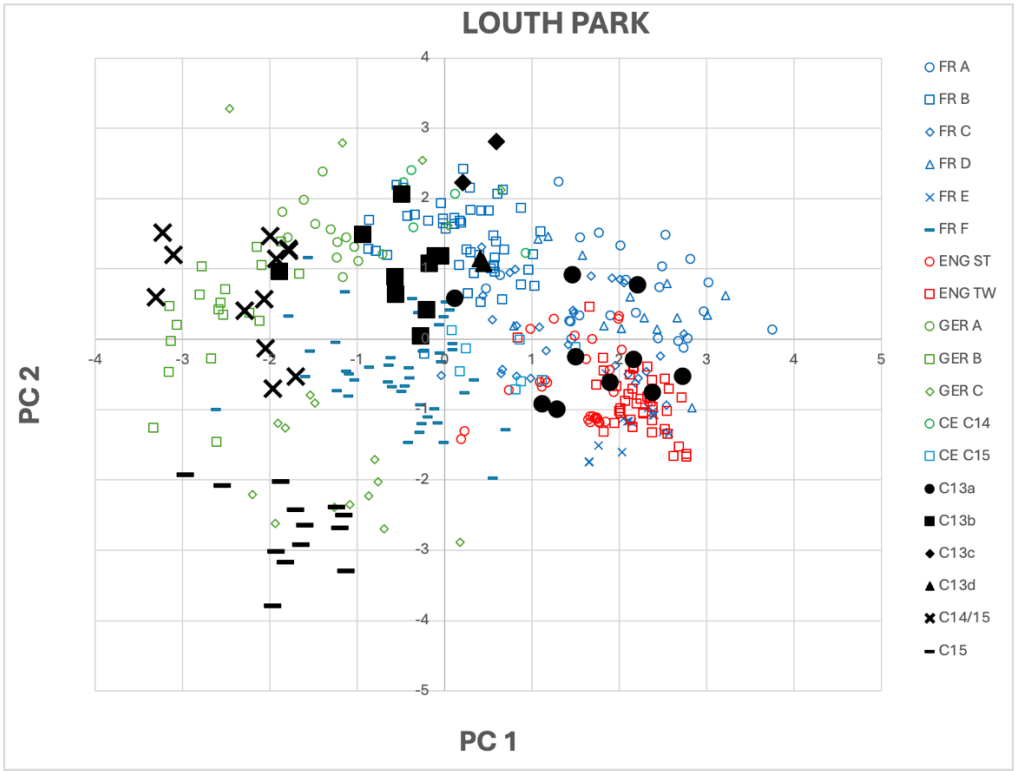


Figure 8.16 PC1 and PC2 bi-plot for Louth Park

8.7 Rievaulx

Figure 8.17 shows that there are 58 glasses from Rievaulx comprising nine separate groups that are dated from the 13th to the 15th century. Three groups from different date ranges (C13, C13/14 and C14a) are compositionally similar and have the same French provenance (FR NC B). See figures 8.18 and 8.19 for scatterplot of potassium vs. calcium and the PCA results.

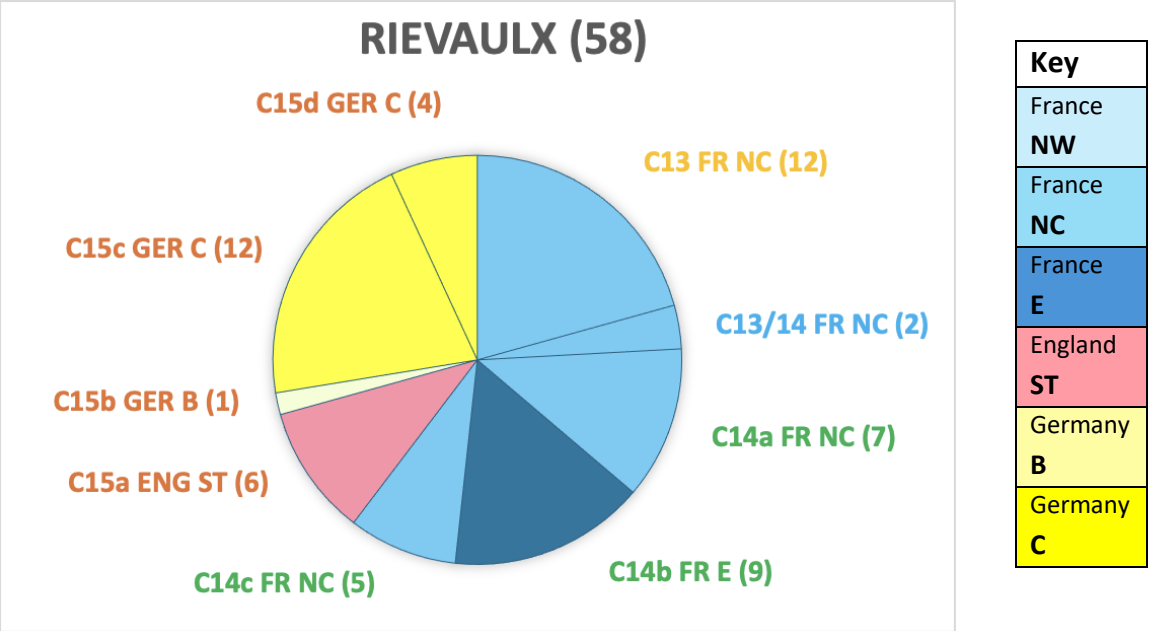


Figure 8.17 Pie chart showing a tentative provenance of 58 glasses from Rievaulx, dated from 13th to the 15th century

All of the glasses are dated to the 13th and 14th century and tentatively provenanced to France:

- The 13th century compositional group, the 13th/14th century group and one of the 14th century groups, C14a, are well-matched compositionally with the same north-central area (FR B). All of the glasses from these groups have similar levels of potassium, magnesium, calcium and silicon.

- C14b is provenanced tentatively to the eastern area of France (FR F1) as both sets have comparable amounts of calcium, silicon and magnesium. The Rievaulx glasses, however, have a higher level of phosphorus, aluminium and manganese.

- C14c has similarities with glasses from the north-central area (FR C3) in the levels of potassium, calcium and manganese.

In the C15th century there are four compositional groups:

- On the scatterplot of potassium vs. calcium (figure 8.18) C15a is shown aligning with English-Staffordshire glasses, although the PCA bi-plot (figure 8.19) shows that this grouping falls in a different quadrant, closer to the French compositions. However, reference to the data set shows that C15a has the same levels of potassium and manganese as the Staffordshire glasses (table 8.4). The high level of manganese and lower level of potassium is key to differentiating Staffordshire glass from French glass

Table 8.4 The average composition of C15a compared with the Staffordshire and northwest French averages

Sample	K2O	Na2O	MgO	CaO	Fe2O3	MnO	Al2O3	SiO2	P2O5	Ca:K
Riev ave	11.42	1.44	5.15	14.41	1.15	1.45	1.84	56.44	5.16	1.3
ST ave	10.78	2.31	7.31	14.69	0.63	1.49	1.74	56.63	3.05	1.4
FR NW A1 ave	14.64	3.43	8.22	13.92	0.55	1.19	1.20	50.70	5.02	1.0
FR NW A3 ave	14.26	3.26	8.83	12.86	0.33	1.31	1.59	52.28	3.69	0.9
FR NW C2 ave	13.81	1.54	4.66	15.35	0.51	0.80	1.44	55.82	3.94	1.1
FR NW D ave	17.11	2.12	5.97	11.76	0.55	0.98	1.19	55.14	3.19	0.7

- The remaining three 15th century compositional sub-groups match with German compositions:
    - C15b has a composition similar to the glasses from GER B1, with similar amounts of silicon, potassium and calcium
    - C15c and C15d both have HLLA compositions and are similar to the HLLA glasses of group GER C, but C15c may have added manganese decolourant

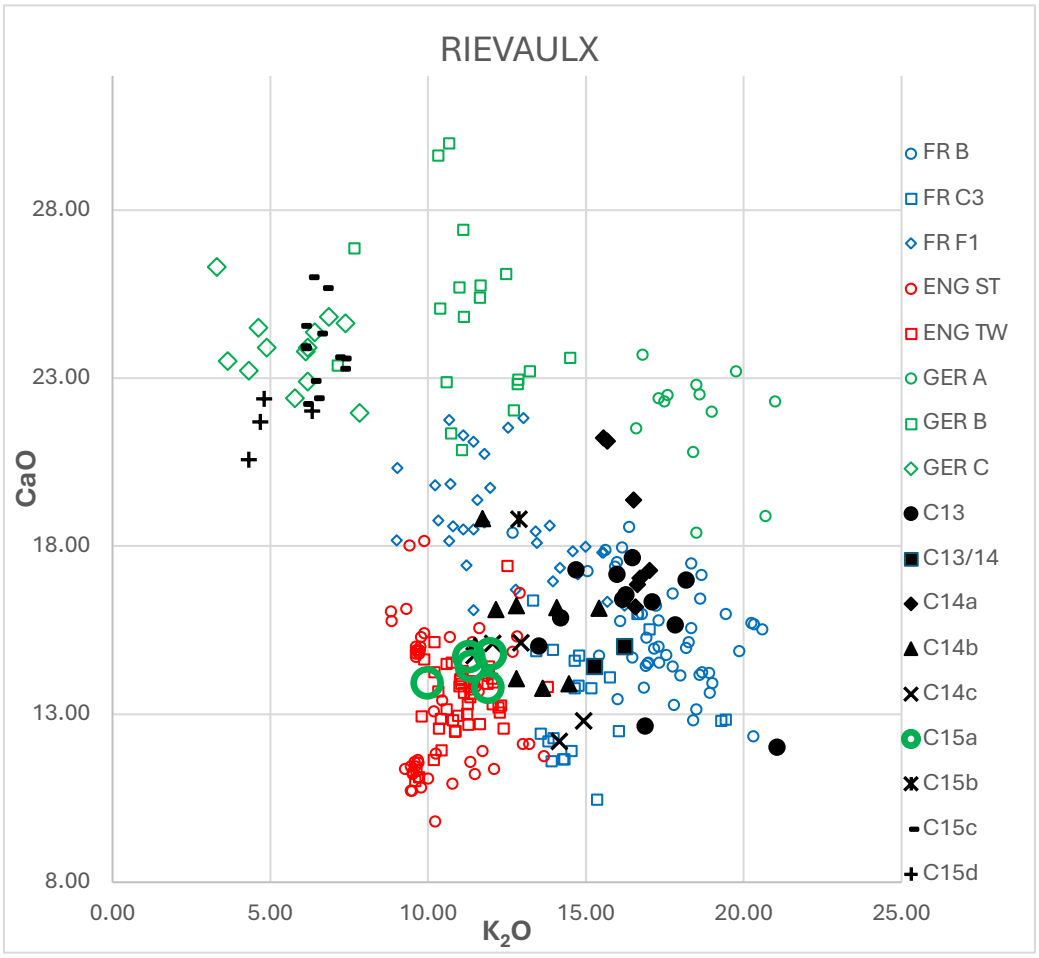


Figure 8.18 Scatterplot of potassium oxide vs. calcium oxide

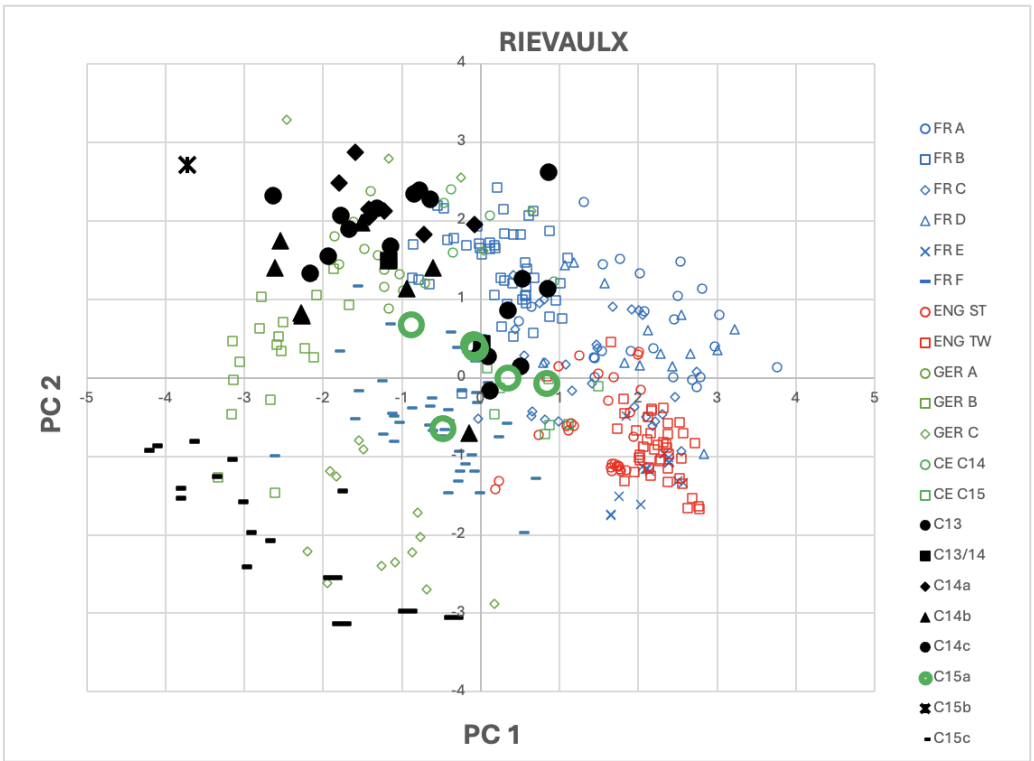


Figure 8.19 PC1 and PC2 bi-plot for Rievaulx

8.8 Whitby

Figure 8.20 shows that there are 29 glasses from Whitby comprising nine compositional groups that are dated from the 13th to the 15th century. See figures 8.21 and 8.22 for scatterplot of potassium and calcium and PCA results.

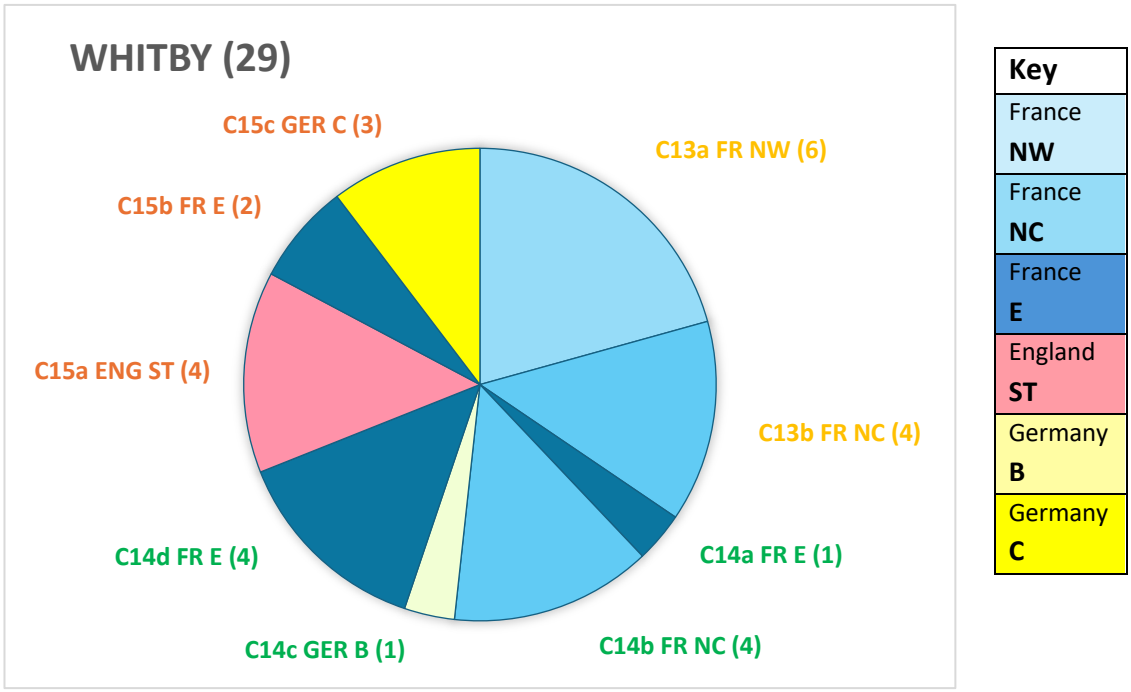


Figure 8.20 Pie chart showing a tentative provenance of 29 glasses from Whitby, dated from 13th to the 15th century

There are two compositional groups in the 13th century date range both of which can be tentatively provenanced to France:

- C13a is similar to the composition of glasses from Normandy in northwest France (FR A1) with comparable amounts of potassium, manganese and silicon

- The composition of C13b is matched to the north-central area of France (FR C1) where there are similar levels of silicon and potassium, as well as a comparable Ca:K ratio of 1.0 (C13b) and 1.1 (FR C1).

That there are two groups in the 14th century, dated early and late:

- The provenance of C14a (early 14th century) has similarities with glasses from eastern France (FR F1) for example, silicon and phosphorus levels are comparable.

- The late 14th century glasses comprise three compositional sub-groups:

- C14b is close in composition to the north-central area of France (FR A2) as they both have comparable levels of magnesium and the same Ca:K ratio of 1.1

- C14c is a single glass that has a similar composition to glasses from Germany (GER B1) with similar calcium, potassium and silicon levels, and a comparable Ca:K ratio, 1.6 (C14c) and 1.7 (B1). However, the C14c composition has a very high level of phosphorus (10.45%), which may be due to surface contamination, although some of the reported values for phosphorus in the regional group are also high (see table 2.6, chapter two, section 2.16)

- The third sub-group, C14d can be provenanced to the eastern area of France (FR F1) as there are similar levels of calcium, potassium, magnesium and manganese. This group is similar to C14a, which is dated earlier and shows a continuity of supply

There are three 15th century groups:

- C15a matches well with English-Staffordshire glass for most elements (table 8.5). Potassium, for example, is similarly low compared with the average northwest French levels

Table 8.5 The average composition of C15a compared with the Staffordshire averages

Sample	K2O	Na2O	MgO	CaO	Fe2O3	MnO	Al2O3	SiO2	P2O5	Ca:K
Whit ave	10.90	1.96	6.56	15.45	0.79	1.49	1.65	56.57	3.61	1.4
ST ave	10.78	2.31	7.31	14.69	0.63	1.49	1.74	56.63	3.05	1.4
FR NW A1 ave	14.64	3.43	8.22	13.92	0.55	1.19	1.20	50.70	5.02	1.0
FR NW A3 ave	14.26	3.26	8.83	12.86	0.33	1.31	1.59	52.28	3.69	0.9
FR NW C2 ave	13.81	1.54	4.66	15.35	0.51	0.80	1.44	55.82	3.94	1.1
FR NW D ave	17.11	2.12	5.97	11.76	0.55	0.98	1.19	55.14	3.19	0.7

- C15b has a tentative provenance to eastern France (FR F2) byway of the similar levels of manganese, potassium and calcium, and Ca:K ratio of 1.5 (C15c) and 1.4 (F2)

- C15c is provenanced to Germany (GER C) as both are HLLA compositions and have similar amounts of potassium, calcium, silicon and phosphorus

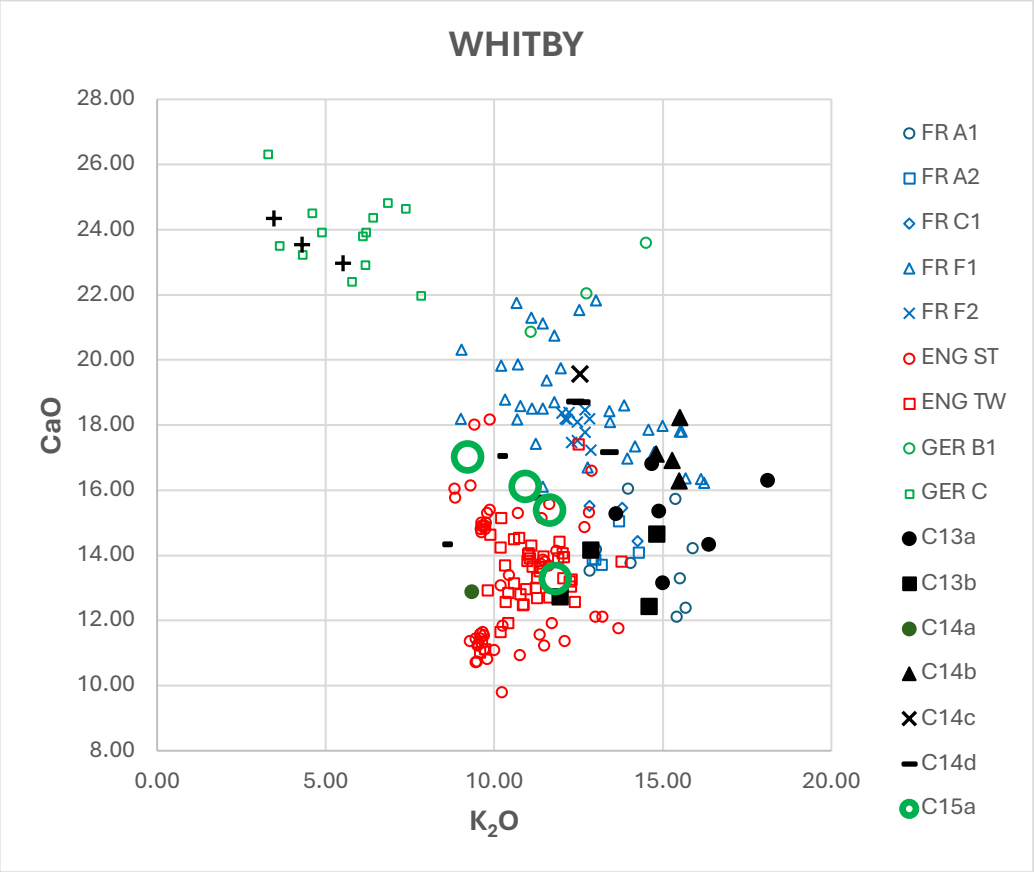


Figure 8.21 Scatterplot potassium oxide vs. calcium oxide

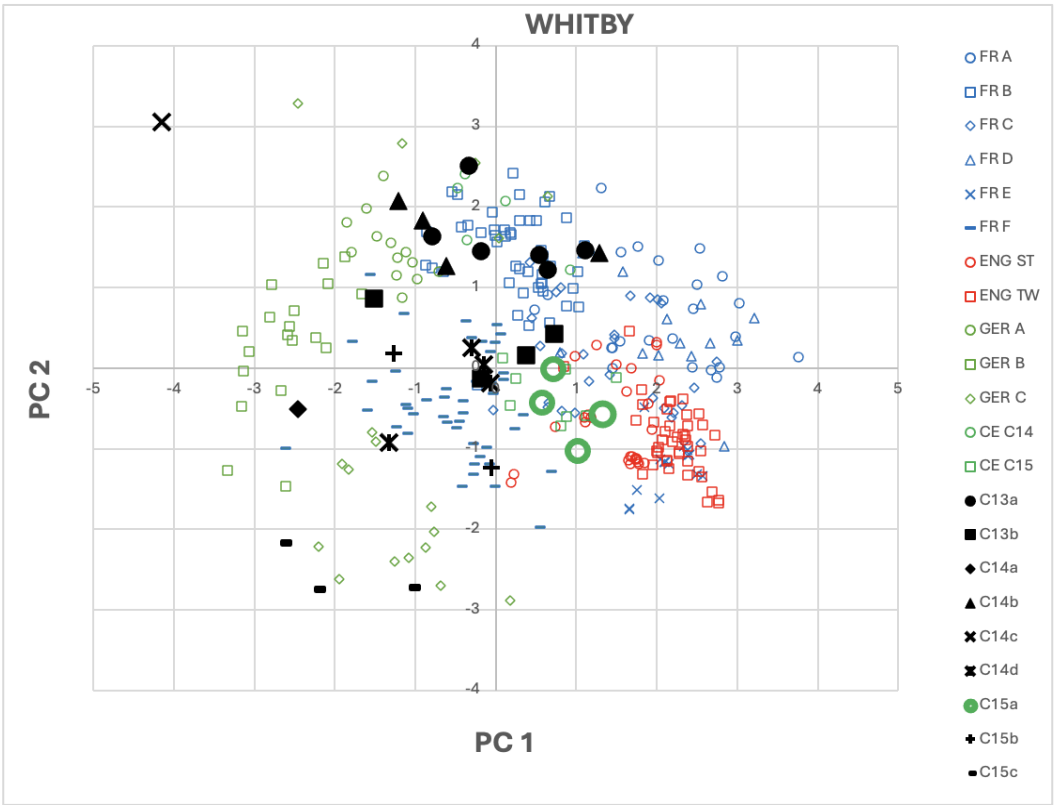


Figure 8.22 PC1 and PC2 bi-plot for Whitby

8.9 Summary of English glass

All compositions from the study that match with the English regional data are presented on the PCA bi-plot, with loadings shown in the vector graph (figure 8.23 and 8.24). It can be seen that some of the points do not fall exactly over the English regional data (coloured red), and some points from all sites align with the French regional data (coloured blue). This is due to the close compositions of English and French glass (particularly from the northwest of France) but may also be due to the limitations of PCA whereby all variables are treated equally. PCA is thus less discerning of, for example, manganese, which is an important element for characterising an English composition, hence PCA is used in tandem with the scatterplots that use data from micro XRF analysis. A more nuanced approach is used by also referring to the full data sets to discern the more characteristic elements of English glass and the levels of, for example, potassium, magnesium, and manganese, as mentioned. A final point is that glassmakers are likely to have recycled varying proportions of imported glass, which would result in some smearing of compositions, particularly at times where a new glass type began to dominate over another.

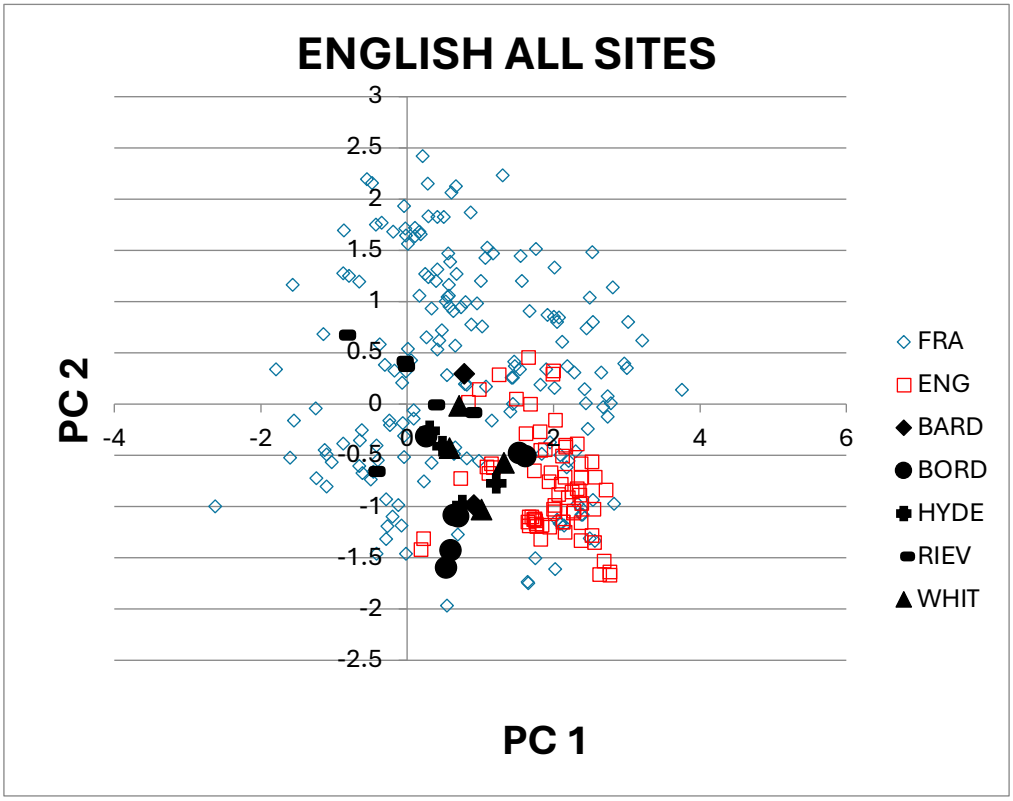


Figure 8.23 PCA bi-plot showing English glass from the study

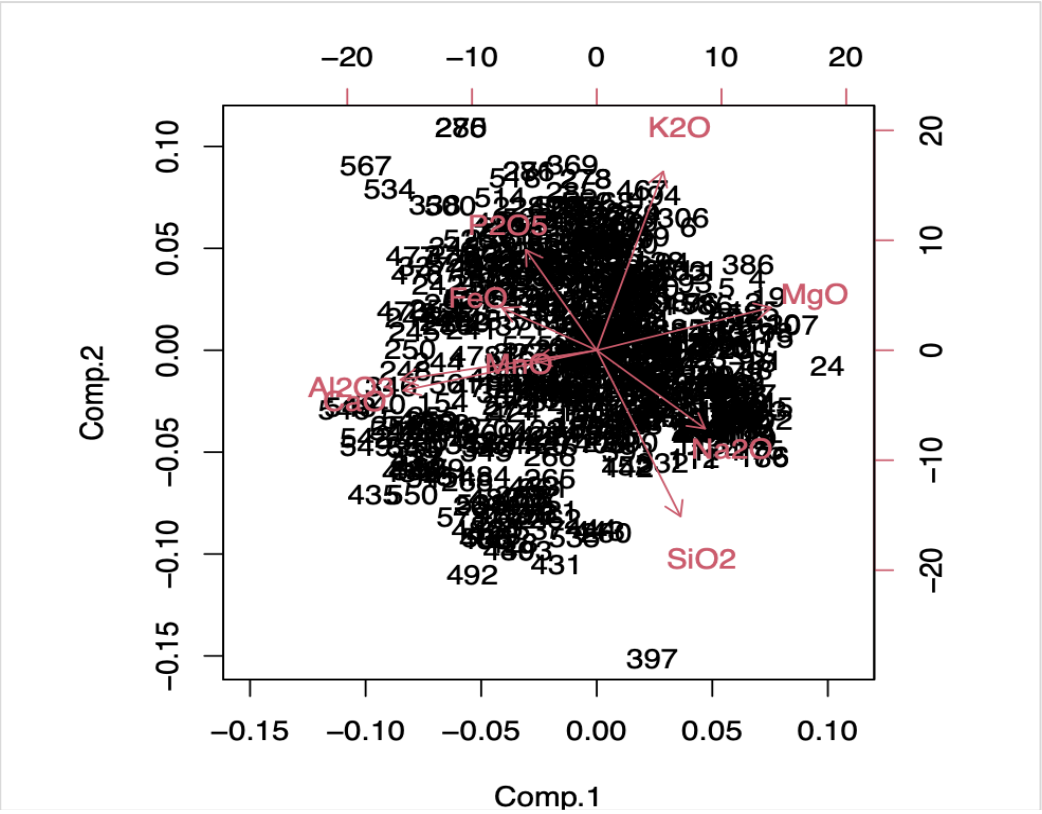


Figure 8.24 PCA vector graph showing loadings for PC1 and PC2 of the data used in the study

8.10 Summary of provenance

The results show that the glasses in the study were sourced from areas in three countries, France, Germany, and in the 14th and 15th centuries from England (figure 8.23). In the following chapter (nine) the provenance of the glasses suggested here is used alongside the stylistic and technical results to discuss the patterns of consumption and the factors that influenced the use of window glass at high status monastic establishments.

Chapter 9

9 Discussion

9.1 Introduction

Research has been conducted on 284 excavated fragments of unpublished, medieval window glass that are dated from the late 12th to the early 16th century from seven Benedictine and Cistercian monastic sites in England. These glasses were discarded during the Dissolution of the Monasteries in the 16th century and have been retrieved during 19th, 20th and 21st century excavations. They are now in the care of a number of archives. Data has been gathered, through a comprehensive analytical programme, to date the glass, assign provenance and determine the quality and method of their manufacture. This chapter analyses these results reported in chapters seven and eight, to establish patterns of consumption at each site, to determine what influenced the consumption choices and ascertain whether window glass made in England was consumed at specific high status sites represented by the abbeys, and why.

The sites are distributed across England with access to differing trade routes and glassmaking areas so that consumption by the monasteries from different areas can be compared. Monastic sites of contrasting religious orders, Benedictine and Cistercian will provide a suggestion about what is typical at these orders and will allow a comparison between them. The changes in consumption relating to the wealth of the monasteries and the proclivities of the abbot, and the changes in the glass composition over time and geographical area, will elucidate the extent to which English glass - a nascent industry at the beginning of the period, was used. Proximity to the glasshouses and the ease of transportation, and the differences between the consumption of window glass by the different orders, may also be factors influencing choice of supply. These patterns are examined alongside workshop practices, which may have influenced cost and availability of particular glass types.

9.2 Consumption of window glass through time

The provenance of the glasses is based on current available data and is suggested tentatively where the regional compositions and the compositions of the glasses in the study match. Table 9.1 shows that window glass of a French origin dominates consumption at the abbey sites until the mid-14th century, after which time glasses from Germany are most prevalent. English glass first appears in the 14th century at Bardney only, but by the 15th century it can be evidenced at four sites (Bordesley, Hyde, Rievaulx and Whitby). No glasses studied here can be currently provenanced to central Europe.

Table 9.1 Table showing origin of glass groupings from all sites in the study using results from chapter eight. The percentage of glass from different origins of each assemblage is also shown.

	Alcester	Bardney	Bordesley	Hyde	Louth Park	Rievaulx	Whitby
C12		**C13 GER A** *l. C12* *(4%)*		**French soda** *l. C12* *(2%)*			
C13	**C13 FR NC B** *c. 1238* *(40%)*		**C13 FR NC B** *e. C13* *(17.5%)*	***C13 FR NC A2*** *e-m C13* *(8%)*	***C14 FR NC B*** *1227-m. C13* *(20%)*	**C13 FR NC B** *1220-39* *(20%)*	**C13 FR NC C1** *1220-25* *(21%)*
			C13 FR NC B *l. C13* *(5%)*		**C13 FR NW A1** *1227-m. C13* *(20%)*		**C13 FR NW A1** 1220-25 (14%)
					C13 FR NW A3 *1227-m. C13* *(8%)*		
C13/14	**C13 FR NW A1** *C13/14* *(3%)*					**C13 FR NC B** *C13/14* *(3%)*	
C14	**C14 FR E F1** *2nd Q C14* *(54%)*	**C14 ST** *c.1340* *(9%)*	**C14 FR E F1** *e. C14* *(25%)*	**C14 FR E F1** *m. C14* *(27%)*		**C13 FR E F1** *1340s* *(12%)*	C**14 FR E F1?** *1310-25* *(3%)*
		C14 GER B2 *c. 1340* *(13%)*	**C14 FR NW** A1 *e. C14* *(35%)*			**C13 FR NC B** *1340s* *(16%)*	**C14 -15 GER B1** *1333-38* *(14%)*
		C13 FR NC B *c. 1340* *(13%)*				**C14 FR NC C3** *1340s* *(9%)*	**C13 FR NC A2** *1333-38 (3%)*
							C14 FR E F1 *1333-38* *(14%)*
C14/15					**C14 GER B1** *C14/15* *(25%)*		
C15		**C15 GER C** *1437-44* *(61%)*	**ENG ST** *c. 1400* *(17.5%)*	**ENG TW** *c. 1446* *(10%))*	**C15 GER C** *m. C15* *(27%)*	**ENG ST** *1490-1500* *(10%)*	**ENG ST** *e-m C15* *(14%)*
				C15 FR E F1 *c.1446* *(6%)*		**C15 GER B** 1490-1500 (3%)	**C14 FR E F2** *e-m C15* *(7%)*
				C15 GER C *c.1446* *(47%)*		**C15 GER C** 1490-1500 (20%)	**C15 GER C** *e-m C15* *(10%)*
C16	**C15 FR NW E1** *c. 1515* *(3%)*						

Key to use of colours in table

France soda	France northwest	France north-central	France east	England Staffordshire	England the Weald	Germany A	Germany B	Germany C

12th century

There are only two glass fragments that date to the 12th century: one possibly French, blue soda glass from Hyde (H41) and one murrey coloured forest glass from Bardney (BA18) that is provenanced to the Corvey and Steim/Bramwald Mountains areas of Germany (GER A). The small sample inhibits further exploration, but no English glass was found in this period; there is no evidence of English glass production at this time and traditionally glass had been imported from Continental Europe (Halahan, 1924, p. 77; Marks, 1993, p. 30).

13th century

The 74 glasses that date to between the early and late 13th century are French, from the north-central region (all sites except for Bardney have examples), and from two areas in the north-western region; Normandy and Brittany (from Alcester, Louth Park and Whitby). There are no samples of glass from eastern France in this date range, and no English glasses are represented. At this time the English glass industry was in a development stage; many authors (e.g. Kenyon, 1967, p. 26) accept the documentary reference to the lease of land in the Weald by Laurence Vitrearius sometime just before 1240 as the earliest evidence of glassmaking in England. However, there is no strong evidence for the consumption of English-made window glass in this period (see section 2.10.8).

13th / 14th century

The three fragments in the 13th/14th century date range are both probably from France: one fragment from Alcester provenanced to Normandy and two fragments from Rievaulx provenanced to the north-central area. There are no eastern French glasses and no English glass, which concurs with the findings from the 13th century.

14th century

The 14th century glasses have a more variable provenance and it is in this period that the first English glasses appear in the study groups. Approximately half of the 55 glasses from this date range are similar chemically to French glasses (examples from all sites except for Bardney, and Louth Park, which has no 14th century glasses in the study): there is a total of 22 fragments that are provenanced to north-central France, (Bardney, Rievaulx and Whitby). There are two groups of German glasses comprising four fragments with close compositions with glasses from Germany (from Bardney and Whitby). There is also a single fragment (W8) where the provenance cannot be ascertained although a tentative eastern French provenance has been suggested based on the closest compositional match. English glass was used at Bardney, dated to around 1330 and comprises two fragments with a Staffordshire provenance. This is the earliest English glass in the study and also some of the earliest evidence of the use of English-made window glass in England; previous evidence is the use of Staffordshire glass at Eynsham, dated (by stylistic analysis) to around the late 13th/14th century (Paynter and Doonan, 2002).

14th / 15th century

It is in this period that a significant change seems to occur in supply patterns, which had previously been dominated by French imports. A group of 12 fragments from Louth Park and dated to 14th/15th century, are matched compositionally with Germany. This is the only group of glasses from this date range in the study, and they are interesting because five of the seven decorated glasses are probably replacement glasses (see section 4.2.1); the remaining two are painted with unusual motifs for which dated parallels could not be found and thus may be an example of a local style of glass painting (see section 4.4.4). There are no English glasses in this date range although there is conjectural evidence for the use of English glass elsewhere, at Gloucester Cathedral in the 1360s, New College Oxford in 1385, Winchester in the 1380/90s (Adlington *et al.*, 2019) and Westminster around 1400 (Kenyon, 1967, p. 29) (see table 2.4, section 2.10.8).

15th century

By the 15th century, nearly two thirds of the groups (totalling 69 fragments) are likely provenanced to Germany (examples from all sites except for Alcester and Bordesley); two groups are compositionally similar to glasses from eastern France. This pattern represents a significant change in supply and consumption patterns at many of the sites, with a more diverse use of sources, predominantly German glasses but also English glass: there are four groups that total 22 fragments that have an English provenance: three from Staffordshire (from Bordesley, Rievaulx and Whitby) and one group of five glasses from Hyde provenanced to the Weald. Two sites (Hyde and Whitby) have glazing episodes that use multiple sources of glass, from English, German and French production areas. The widespread use of English glass at the study sites correlates with evidence for the use of Staffordshire glass elsewhere in this period, at York Minster in 1405-08 (Adlington, 2019) and at Tattershall in 1480 (Welch, 1997, p. 35). Based on proximity, the glass used at Coldharbour in London in 1485 (Woodforde, 1950; Marks, 1993, p. 31) was probably from the Weald.

16th century

There is one 16th century glass in the study that matches compositionally with glass from the northwest France (Alcester). There are no English glasses from this period, although there is only one sample in this date range. During this time the Wealden industry was fairly small-scale with documentary and archaeological evidence of a small number of furnaces operating, whereas archaeological evidence suggests that the industry in Staffordshire was more active (Welch, 1997, p 35; Kenyon, 1967, p. 13) (see section 2.10).

9.2.1 The early dominance of French glass

By the mid-12th century French glassmakers were supplying the window glass for the new Gothic cathedrals and monasteries, for example St Denis in Paris (see sect 2.12). French window glass was also exported to England: excluding one fragment of 12th century German

glass, all of the uncoloured and coloured glass used at the study sites between the late 12th century and around the 1330s was supplied by the French glasshouses from the northwest, north-central and eastern regions. After this date the dominance of French glasshouses declined.

The decline in French window glass use at the study sites can be explained in part by political events. In the 14th century, war with England and concomitant economic disruptions, combined with the devastation of the Black Death resulted in the severe disruption to the French glassmaking industry. Accordingly, there are only six examples of French glass in the project that are dated post mid-14th century; these are from Whitby and Hyde in the 15th century and a single, possibly 16th century glass from Alcester. It is possible that the early 15th century glasses were sourced from stocks already held by glaziers or warehouses, just as some of the glass used in the glazing of the chapels at Westminster and Windsor during the Black Death had been obtained from warehouse stocks (Marks, 1993, p. 30). In the hiatus of French production and disruptions to the trade routes and supply networks alternative sources of glass were used at the monastic sites, from Germany and England. At least by late 15th century, glassmaking in northern France had resumed and the 16th century Alcester sample from northwest France may be from recommenced glass production in this region

9.2.2 Later German dominance

Evidence for production of window glass in Germany dates to the 12th century, to the Bramwald Mountains and by the mid-13th century was well established in the Rhine-Meuse area, see sect 2.13. In the study, there is a single German glass that is dated to the late-12th century (GER A), which interestingly is a specialist glass because it is murrey-coloured, yet there is no further consumption of German glass at the study sites until the glazing episodes in the 1330s when glass with a German B provenance starts to be used alongside French glass. This hiatus at the sites is perhaps testament to the strength of French production, the tradition of buying French glass and the established trade network rather than a deficiency in the German enterprise. There were afterall, well established trade links between Germany and England in the medieval period, and by the 13th century the Hanseatic traders were a strong and organised group (Kermode, 1998). The resumed use of German glass at the study sites in the 14th century coincides with changes to the German recipe and perhaps to a lesser extent the Hundred Years War. The war with France, which began in 1337 may have impacted trade through intermittent disruptions to sea freight, however, in the first half of the 14th century all sites excluding Louth Park use French glass, thus in this period at least, the war is unlikely to have had a major effect on consumption. More likely is the gradual change to the recipe. In the 14th and 14th/15th century the recipe is calcium-rich (GER B) and in the 15th century, the German HLLA composition (GER C) dominates consumption at the study sites for the remainder of the study period. As discussed elsewhere, the HLLA glass was good quality and cheap and may have been a preferred choice to more expensive glasses from elsewhere. In the 15th century, the patronage of the fenestration in religious establishments by donors may

have driven preference for cheap, more durable glass over the prestige of more expensive, and possibly better quality window glass, for example from France (e.g. Caen, 2009, p. 236) (see section 4.5.2, chapter four).

9.2.3 The emergence of English glass

There is documentary evidence of window glass production in England from around 1240 although at this time the nascent industry was small-scale with glasshouses also manufacturing vessel glass (Kenyon, 1967, p. 13). English window glass was consumed at the study sites from around 1330 at Bardney, and throughout the 15th century at Bordesley, Hyde, Rievaulx and Whitby where English glass may have been preferred to the more expensive continental glass with higher transport costs and perhaps a longer delivery time. There are only a few examples at each site except for Bordesley, where there are seven fragments. Here English glass was used exclusively for the glazing episode dated to around 1400, when major building work at the abbey was undertaken. None of the English glasses are coloured although at Bordesley and Whitby some are silver-stained. A predominantly colourless scheme highlighted with yellow and possibly other colours in the silver stain range would have been an economical option; English glass was cheap to buy and transport (Marks, 1993, p. 31), which was perhaps its attraction (to a parsimonious patron). French glass may have been unavailable (during its hiatus) and German glass may have been difficult to transport to the west of the country, and was therefore, possibly more expensive. English glass was available, (although not used in great quantity); this is evidenced through the glazing in the mid-14th century of the royal chapels, and of further uses in the 15th century, for example at York Minster (see section 2.10.8).

9.3 The monasteries and their fluctuating fortunes

The changing fortunes of the monasteries, possibly, indirectly could have had an effect on the adoption of English glass in glazing schemes, whether through cost, availability or preference. Windows were expensive and available funding fluctuated with the fortunes of the abbeys. As discussed in section 5.3, all abbeys in the 11th and 12th centuries received grants and donations to become established, and many abbeys also had earned income, for example from sheep farming at Rievaulx, Bardney, Louth Park and Bordesley. Wealth was displayed at this time through vast amounts of glazing, much of which was expensive, imported coloured glass. During leaner times, glazing may have relied on funding by donors who perhaps kept more of an eye on 'the bottom line' and chose less colourful schemes that relied more heavily on the use of colourless glass and silver stain. However, as discussed in section 9.5.2. below, there were other mitigating factors concerning the consumption of coloured glass in the later period. The glazing episodes at each site are summarised in table 9.2, below, and discussed here with reference to building activity and events at the abbeys (presented in EIDF for each

site in the results for all sites, chapter seven) as well as factors more broadly that may have influenced the glazing commissions.

12th century

At Bardney, the use of glass is connected with the completion of the church and presumably other key buildings that include the refectory (see sections 5.5.2 and 7.3.2). At Hyde, the glazing is connected with the re-building programme dated to around 1182 after the abbey was destroyed during the Anarchy (see section 5.5.4 and 7.4.2).

13th century

All sites, excluding Bardney, undertook new glazing commissions in the 13th century that tied in with the construction of buildings in the monastic range. Evidence from Louth Park show that building was extensive and swiftly undertaken (Coppack and Harrison, in preparation). Prosperity was maintained at least until the end of the century at all sites excluding Bardney. Here, as the first monastic establishment in the affluent Witham Valley in Lincolnshire it received generous funding at its foundation. However, it failed to compete for patronage with the influx of newer monasteries in the area, which included Louth Park, and its fortunes declined (see section 5.5.2).

13th/14th century

In the late 13th/early 14th century, sheep scab decimated income from the sale of wool, and abbeys such as Louth Park and Rievaulx incurred heavy losses, although at Rievaulx, glazing was installed in the late 13th century and in the 13th/14th century. There is no evidence to show how this was funded but may have relied on donations.

14th century

Despite documented debt at Alcester and Bardney new glazing was installed in the 14th century, and also at Hyde, and as proposed for Rievaulx above, donors may have funded the fenestration although there is no known evidence. At Whitby, it is known that glazing was funded using the fabric fund (see 5.5.7). Perhaps the most significant event for all abbeys was the Black Death in the mid-14th century with recurring bouts throughout the century, which devastated monastic communities and income from estates was substantially reduced. There was a hiatus in glazing at all sites until the 15th century, excluding an episode at Louth Park dated 14th/15th century although there is no known construction work or events at the abbey that tie in with this glazing episode.

15th to early 16th century

Throughout the 15th century and into the early 16th century all of the abbeys in the study undertook new glazing. There was a religious revival following the Black Death and donations

may have funded the repair and the remodelling of the abbeys in the study as the claustral range was contracted to fit smaller communities, for example at Alcester (Threlfall, 1939) or the major rebuilding project at Bordesley (Hirst, Walsh and Wright, 1983, p. 54).

Table 9.2 Summary of building and events at the abbeys for each date range when glazing was installed (for dates of episodes refer to table 9.1 above)

	Alcester	Bardney	Bordesley	Hyde	Louth Park	Rievaulx	Whitby
C12		Completion of the church		Rebuilding programme			
C13	Building of Chapter House		N/A	Rebuilding programme	Campaign of building	Building work and extensions	Phase 1 of building
C13/14	Possible donor window					N/A	
C14	Possible donor window	Possible donor window	Rebuilt gatehouse chapel and other renovations	N/A		Church and key buildings remodelled	Phase 3 of building Use of fabric fund
C14/15					N/A		
C15		Possible donor windows	Large-scale rebuilding programme	Rebuilding of the church and other renovations	N/A	Extensive remodelling of claustral range and new cloister glazing	Completion of west end of church and Great West Window
C16	Renovations programme						

Summary of consumption relating to the affluence of the abbeys

It can be seen that glazing episodes can sometimes be tied to building work at the abbeys, including renovations and remodelling for the smaller communities. On the whole, fenestration fluctuated with the flow of income and a hiatus in glazing coincided with periods of poverty and the aftermath of the most devastating attack of the Black Death in the mid-14th century. Where glazing was undertaken during known periods of poverty, it is suggested that these were donor windows, for example at Alcester and Bardney, although records for such are scarce. Nonetheless, the involvement of a donor may have influenced the choice of window glass: the donor may have requested cheaper, perhaps local, English glass for example, or indeed more prestigious, but more expensive continental glass. In the 15th century, French glass, for example had a reputation for quality (see section 4.5.2 below). The window design, particularly in the choice of colours may equally have influenced the source of the glass used; for example, coloured glasses were probably obtained from regional specialists (see section 9.5.1 below). The donor may have requested a figural window featuring themselves, perhaps using multi-coloured glasses (Dugdale, 2010, p. 23; Márkus,

2025, p. 554). An example of such a window is at St Denis in York (see Marks, 1993, frontispiece).

9.4 Workshop practice and compositional change

Differences in the composition of the glasses over time and geographical regions reflect different workshop practices: some compositions show a change to the HLLA recipe or evidence of added cullet, and high levels of sodium and manganese in some compositions may be a result of practices to refine the quality and colour of the glass.

9.4.1 Glass types and HLLA

The glass composition on the continent evolved from one characterised by a high wood ash to silica ratio (which was produced in France, Germany and England) to a one with a low wood ash to silica ratio, which manifests itself as HLLA and which was produced in Germany from around 1400 (GER C) (Wedepohl, 1997) (see section 2.3.5). Calcium-rich forest glass was also produced from the first half of the 14th century, predominantly in Germany (GER B). Table 9.3 shows the glass types used at each site including the 12th century single soda glass.

Table 9.3 Numbers of fragments of each glass type at each abbey

Glass type	ALCESTER	BARDNEY	BORDESLEY	HYDE	LOUTH PARK	RIEVAULX	WHITBY	No.
Soda (late C12)	0	0	0	1	0	0	0	1
Forest (late C12-C16)	37	6	40	25	24	41	25	198
Ca-rich forest (C14-C15)	0	3	1	0	12	1	1	17
HLLA (C15)	0	14	0	22	13	16	3	68

The change to an HLLA recipe in Germany was concomitant with an improved furnace design that could fire to a higher temperature and the production of increasingly thinner glass using the broad method; the glass was thus cheaper to produce than forest glass (economies of scale probably also contributed). In addition, HLLA glass was more durable because of the low alkali content (Wedepohl, 1997, p. 250), and its greater clarity ensured that it was an attractive proposition for the customer. It may also have had prestige especially in relation to English glass, which in the 15th and 16th centuries did not have a good reputation (see section 2.10.8). All of the English glass in the project is dated from around 1330 to 1500 and has a forest composition and it is only from the mid-16th century that the composition in England changed to HLLA with the arrival of continental glassmakers in the Weald, described by Kenyon (1967, p. 14) as a ‘technical renaissance’.

9.4.2 Cullet

Many of the uncoloured glasses analysed contain small amounts of copper, cobalt and lead contaminants derived from coloured and painted cullet and possibly lead came. The cullet was used to facilitate the melting of the glass batch and there is archaeological and documentary evidence of a trade in cullet, as shown by the stockpiles of cullet dating to the 16th century excavated from Little Birches in Staffordshire (Welch, 1997, p. 19). Cullet probably also reduced the cost of the glass by bulking out the batch. The amount of cullet used in a recipe may have varied according to its availability and also to its need, for example, when plant ash used for the flux was in short supply and thus would have been expensive, and more cullet may have been used to augment the batch of glass.

Table 9.4 shows that the use of coloured cullet is most widespread in the 14th and 14th/15th century demonstrating that the glassmakers were perhaps being less discriminating about the quality of the cullet that was added to the glass batch. This may be due to a scarcity of non-coloured (uncontaminated) cullet. Windows in monasteries were not static and were often replaced over time and it is possible that some of the cullet used in the 14th and 14th/15th centuries was some of the earlier, brightly coloured window glass that may have been used in biblical-themed windows of the 12th century (see section 4.4.1).

By the 15th century, there are just three sites with glasses showing evidence of added coloured cullet and this perhaps relates to the change to the HLLA recipe and more plentiful supplies of colourless glass for reuse.

Table 9.4 Evidence for the use of coloured cullet in the study glasses

	Alcester	Bardney	Bordesley	Hyde	Louth Park	Rievaulx	Whitby
C12							
C13	Cu		Pb		Pb		Cu/Pb
C13/14							
C14 & C14/15	Cu/Pb	Co/Cu		Co	Pb	Pb	Cu/Pb
C15				Pb		Pb	Co
C16							

Table 9.5 shows the provenance of the groups of glasses with evidence of added coloured cullet. All of the glasses are forest type from France (northwest, north-central and eastern), and Germany (B), which has a calcium-rich forest composition. There are no HLLA glasses from Germany (C). The table also shows that added coloured cullet is evident in four of the five English groups of glass, from Staffordshire and the Weald, suggesting that the use of cullet in English-made glass was probably a routine workshop practice at times. As discussed elsewhere, all of the English glass is uncoloured, therefore the presence of colourants in measurable quantities is a strong indicator of the practice.

Table 9.5 Provenance of glass with evidence of added coloured cullet for each site by date range

	Alcester	Bardney	Bordesley	Hyde	Louth Park	Rievaulx	Whitby
C12							
C13	FR NC		FR NC		FR NW		FR NW
					FR NC		FR NC
C13/14							
C14	FR E	FR NC		FR E		FR E	FR E
		GER B					
		ENG ST					GER B
C14/15					GER B		
C15				FR E		ENG ST	ENG ST
				ENG TW			
C16							

9.4.3 Salt (sodium chloride)

Salt (NaCl) can be used as a fining agent in the production of the glass (for example to remove air bubbles) and several analytical studies describe its use, for example in 13th century Normandy (Lagabrielle and Velde, 2005) and in Germany in the 15th century (Wedepohl and Simon, 2010; Schalm et al., 2003; Caen, 2010). It is possible to show that salt may have been used by way of correlating high levels of sodium and chlorine in the compositional data (see figures 9.1-9.4 below). There are caveats, however: chlorine has low solubility and is volatile at high temperatures (Gerth et al., 1998, p. 226) and because sodium has a low atomic mass, it is poorly characterised using micro XRF (in this study, although the calculated limit of detection for mounted standards was 0.9%, for the windows only amounts of sodium over around 2% are considered reliable (see section 6.7.2)). Thus, distinguishing such glasses using the compositional data from micro XRF analysis is problematic. Nonetheless, there are three groups of glasses in the study that show possible evidence of added salt by way of correlating high levels of sodium (2-6.5%) and chlorine (0.3-0.5%) (table 9.6).

Table 9.6 Groups of glasses with added salt

Site	Fig.	Compositional group	No, of samples	Provenance	Appearance
Louth Park	1, 5	C13a, forest	10	Brittany, A3	Few small bubbles
Bardney	3	C15a, HLLA	6	Germany C	Small bubbles (B32) but weathered crust prevents observation
Hyde	4	C15c, HLLA	7	Germany C	Many small bubbles

Table 9.6 shows that in the 13th century date range salt was probably added to glasses with a forest glass composition likely sourced from Brittany (A3). In the 15th century, the glasses with evidence of added salt have HLLA compositions and are provenanced to Germany (GER C). Figure 9.1 shows only a moderate positive correlation between chlorine and sodium for Hyde (R=0.5201) and the R value shown in figure 9.2 suggests a stronger correlation between chlorine and sodium at Bardney (R=0.912). At Louth Park, chlorine correlates with sodium up to a level of around 3% (figure 9.3, where chlorine has been multiplied by 10 to show better

the correlation) above which, chlorine fluctuates because of its volatility (Gerth et al. (1998, p. 226). Figure 9.4 shows a strong positive correlation of chlorine and sodium in the Louth Park glasses up to around 3% sodium (R=0.9814).

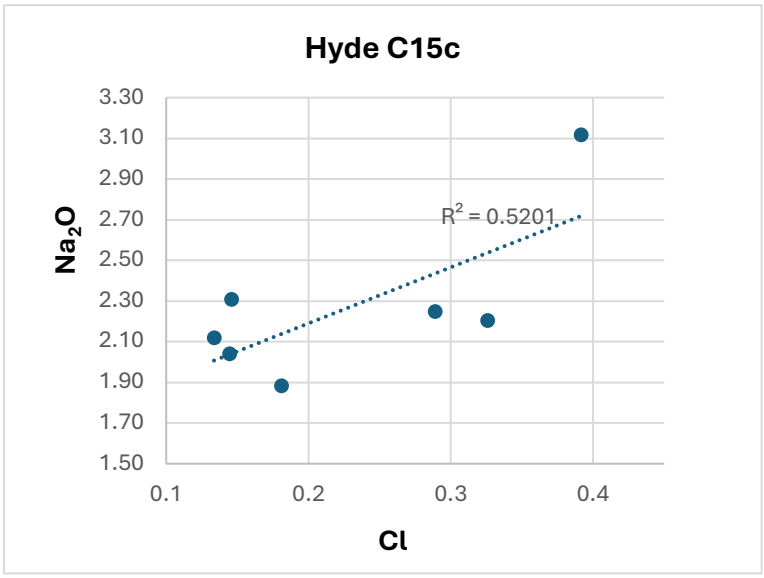


Figure 9.1 Correlation of chlorine and sodium suggesting salt was used in the C15c group from Hyde

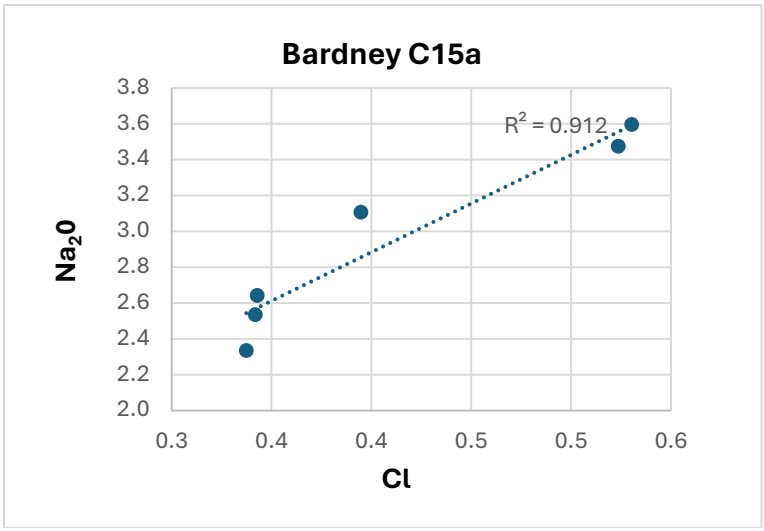


Figure 9.2 Correlation of chlorine and sodium suggesting salt was used in the C15a group at Bardney

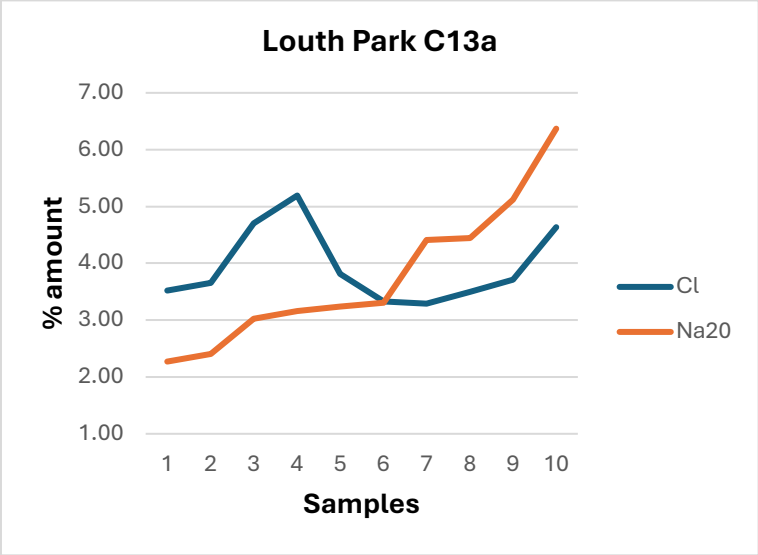


*Figure 9.3 Correlation graph of chlorine (*10) and sodium suggesting salt was used in the C13a group at Louth Park*

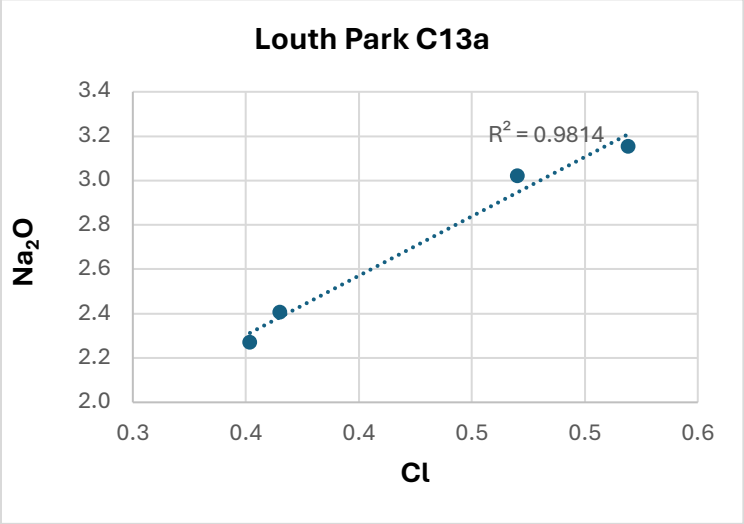


Figure 9.4 Correlation of chlorine and sodium (up to around 3%) suggesting salt was used in C13a group at Louth Park

All of the 15th century HLLA glasses from Germany with added salt are coloured (green, red and blue), excluding one uncoloured glass used at Bardney (B21) and thus these glasses may be the output of a specialist glasshouse. At Louth Park all of the glasses are uncoloured (Brittany provenance). The workshop practice of adding salt in the earlier period may therefore be a regional preference limited to the glassmaking areas close to the coast and sources of salt; in Brittany, for example, there was an industry producing salt from brine in the medieval period (Sherborne, 1971, p. 8), a process that is described by Agricola (1556, p. 545). It is also noted that sodium may be present naturally in small quantities in the wood ash (Jackson, Booth and Smedley, 2005). A microscopic examination of six of the glasses mentioned above (figures 9.5 to 9.10), shows mixed results in terms of the presence of bubbles in the fabric of the glasses.

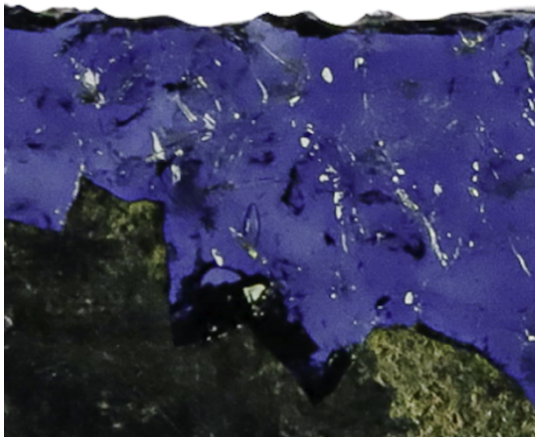


Figure 9.5 BA24

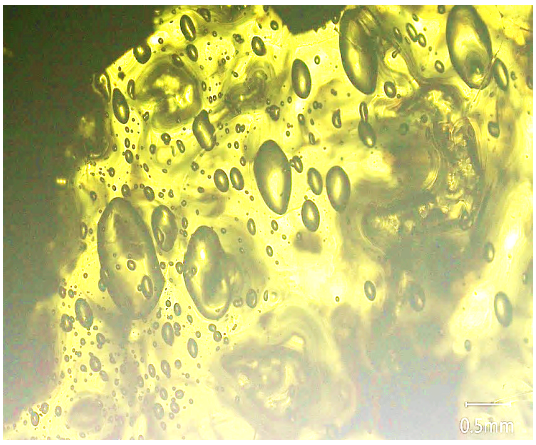


Figure 9.6 BA25

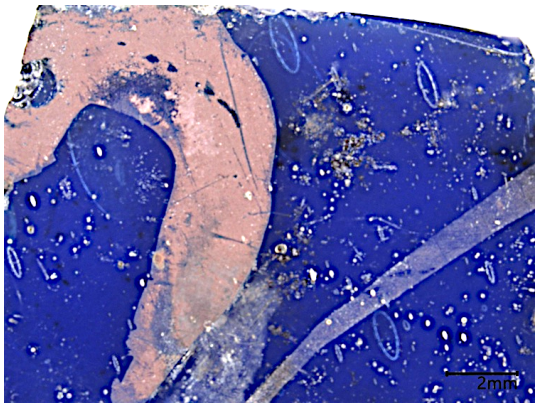


Figure 9.7 H49

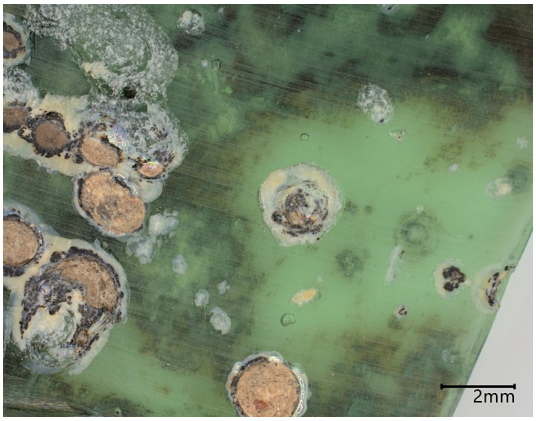


Figure 9.8 L11

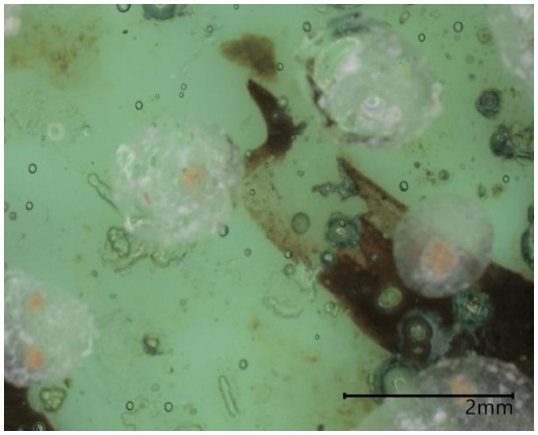


Figure 9.9 L13

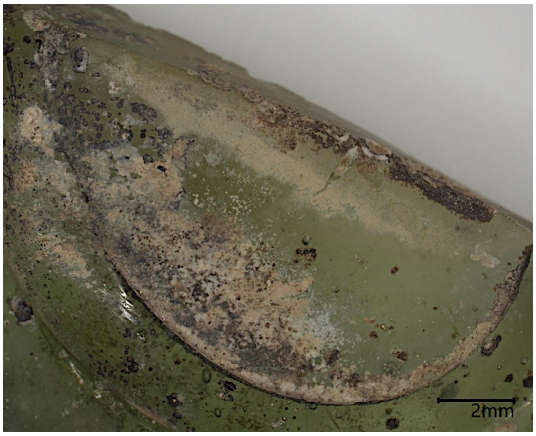


Figure 9.10 L36

Figs 9.5 to 9.10: BA24, BA25, H49, L11, L13, L36; figure 9.10 is an image of a tool mark on L36 but shows no bubbles in the glass fabric. Bardney, BA24, a blue glass (figure 9.5), has only a few small bubbles, however, BA25, a green glass (figure 9.6), has many large bubbles. These two samples have a similar base glass composition but are from different batches (blue and green) and it may be the case that BA25 was made early on in the melt of the green glass before it had refined. Bubbles are also visible in the Hyde sample (H49) (figure 9.7); however, at Louth Park, bubbles are absent, or very small and few in all samples (L11, L13, L36) (figures 9.8-9.10). These glasses are likely provenanced to Brittany (A3), where perhaps the glassmakers were very proficient at refining the glass using (the local) salt.

The German production areas that produced glass with added salt also produced glass with a high amount of manganese de-colourant. This is discussed below.

9.4.4 Manganese decolourant

The compositional data shows that during the 15th century glasses from three study sites with a German (C) composition were decoloured (whether through the raw materials or, as Biringuccio records in the 16th century, through a deliberate addition of manganese (Smith and Gnudi, 1990, p. 132)). The sites are listed (table 9.7), also giving details of the glazing episodes for each group. Other than the blue glass from Bardney all other glasses are colourless or have a very pale green tint (including the colourless area of the flashed glass).

Table 9.7 Groups of glass containing elevated levels of manganese (GE abbreviation for glazing episode)

Site	Compositional group	No. samples	Glass colour	Painted decoration	Glazing episode (GE)	Date of GE
Bardney	C15b	8	Very pale green and colourless (6), coloured glasses (2): blue, and flashed red where the colourless area only was analysed	Architectural, diaper	New frater windows	1437 -1438
Hyde	C15e	8	Colourless, of which 7 are silver-stained	Architecture, lettering, border and beading, all silver-stained excluding H50, lettering	Major repairs and refurbishment around the monastic site	c. 1446
Rievaulx	C15c	12	Colourless (10) and very pale green (2)	Architectural, lettering	Remodelling and glazing of key buildings in the monastic range	c. 1490 -1500

A high level of manganese de-colourant is only found in the later 15th century German glasses. A high manganese recipe used by some glasshouses occurs with the HLLA recipe and it may be that the glasses were poor quality in terms of their colour, and manganese was added to denude the glasses of a green tint. It is possible that these colourless German glasses were sourced for their clarity to be used for windows with particular decorative motifs and designs. As shown in table 9.7, the decorative designs applied to the high manganese glasses include architectural designs, lettering and diaper patterns yet a similar range of designs is found on the 15th century German (C) glasses without the elevated levels of manganese, and which are naturally tinted green (examples at Louth Park and Rievaulx). This suggests that the choice regarding how glasses were used, at least in terms of colourless or tinted glass may have been made by the glazier as the window was being constructed. On the other hand, the glazing episodes using these high manganese glasses are parts of repair and refurbishment work at Hyde and the contraction of the monastic range at Rievaulx, thus two commissions that probably required considerable glass, and which may explain the use of two slightly different

compositions from the same production area to meet the demands of the large glazing episodes. Only the German glasses contain elevated levels of manganese, and German producers may therefore have had market-advantage in the 15th century over the poorer quality, green-tinted glasses, for example, as produced by the English glass centres.

9.5 Colour

There are 62 fragments of coloured glass in the study of five different colours, murrey, amber, green, red and blue. Table 9.8 shows that coloured glasses were used at all sites, as might be expected in religious glazing schemes: in the 12th to 14th century, all five colours were used and other than two green glasses from Bardney, all of the glasses from the late 14th/15th century are red or blue. Red glass can be split into three types based on the chronological development of the technique used in its production (see section 2.4). In the study, streaky red was used only in the 13th century; striated red was used up until the mid-14th century and flashed red was used from the 14th/15th century. This concurs with the findings from Kunicki-Goldfinger et al., 2014 (p. 92).

Table 9.8 Coloured glasses found at each site according to date range; number of fragments in brackets

Date range	Alcester	Bardney	Bordesley	Hyde	Louth Park	Rievaulx	Whitby
C12		Murrey (1)		Blue (1)			
C13	Red (1)		Blue (1)		Red (1)	Murrey (1)	Blue (1)
	Amber (4)		Green (1)		Amber (1)	Green (1)	
C13/14		*No glasses in this date range*				murrey (1)	
C14	Red (2)	Red (1)	Red (1)			Red (1)	Red (2)
	Blue (1)	Blue (1)	Blue (2)			Blue(4)	Blue (1)
	Amber (1)		Amber (4)			Amber(1)	
	Green (2)					Green (4)	
	Murrey (1)						
C14/15					Red (1)		
C15		Blue (4)		Red (3)	Blue (1)	Red (1)	Red (2)
		Green (2)		Blue (4)			
C16							

Murrey and amber glasses were both consumed until the first half of the 14th century. The murrey glasses were used for figural details and drapery, for example ALC 75, dated to early 14th century that depicts a forward-facing head. Westlake (1882, p. 2) explains that from the 14th/15th century, figural details such as these were painted onto uncoloured glass and in the study there are four late 15th century examples that include a hand (R21), foot (R22), face (R23) and a monk's tonsured head (L28). Amber glass was utilised for grisaille, border patterns and lettering; examples of 13th century Lombardic lettering on amber glass are ALC 44, ALC 46 and ALC 47. Gothic lettering replaced Lombardic lettering around the mid-14th century (Marks, 1993, p. 167) and was painted onto uncoloured glass and there are several examples in the study, including English glasses depicting Gothic lettering (for example, R29, R30, R31, H53). The Gothic lettering is predominantly painted using dark brown or black paint, clearly planned to be highly visible, perhaps from a distance depending on the location of the window installation (it is noted that the darker paint is also used on the 15th century colourless glasses depicting black and white tessellated flooring, for example H91 and H92). Blue glass was consumed throughout the study period and red from the 13th century. Both colours were widely used for colouring drapery, foliate and diaper (for example H41, R50). Green was used from the 13th century for colouring foliate and vegetal motifs (for example R2). The limited palette of the 15th century is discussed below, 9.5.2.

9.5.1 Provenance of coloured glass

There is no evidence to date to show that coloured glass was produced in England until the end of the 15th century (Brown, 2019, p. 11; Marks, 1993, p. 30) and the lack of coloured glass production in England may in part explain the absence of English glass, or relatively low use, throughout the study period. Table 9.9 shows that other than a German (A) murrey glass that is dated to the late-12th century, all coloured glasses up until the mid-14th century are French, provenanced to the northwest, north-central and eastern regions. After the mid-14th century, the only coloured glass consumed is from German production centres (B and C), excluding two early 15th century flashed red glasses from eastern France, which may be from stock.

As shown in tables 9.8 and 9.9, from the second half of the 14th century the palette was limited predominantly to blue and red, with two examples of green glass. This restrained range of colours may relate to changing tastes, perhaps a reaction to the boldness of colour in the earlier 14th century schemes (pre-Black Death). Knowles (1922) however, claims that glaziers were unable to source sufficient coloured glass from the continent and that the large areas of colourless glass that characterise late 14th and 15th century windows are due to this shortfall. During the religious revival of the 15th century and the increased church and chapel building, monastic improvements and patrimony, it was probably the case that the supply of continental glass was unable to meet demand.

Table 9.9 Provenance of different colours of glass at all sites and date ranges; number of fragments in brackets

	Murrey	Blue	Green	Amber	Streaky red	Striated red	Flashed red
C12	GER A (1)	France (1)					
C13	FR NC (1)	FR NC (1)	FR NC (2)	FR NC (4)	FR NC (1)	FR NW (1)	
		FR NW (1)		FR NW (1)			
C13/14	FR NC (1)						
C14	FR E (1)	FR E (5)	FR E (3)	FR E (4)		FR E (2)	
		NC (1)	FR NC (3)	NC (1)		FR NC (3)	
		NW (2)		NW (1)		FR NW (1)	
		GER B (1)					
C14/15							GER B (1)
C15		GER C (9)	GER C (2)				FR E (2)
							GER C (5)
C16							

It may have been the case that the 15th century German producers of the HLLA glass could not make the range of colours that had been supplied previously by the French glassmakers since murrey and amber glasses are missing from the German repertoire: Weyl (1951, p. 129) reports that 'in order to achieve an intensive manganese (murrey) colour ... glasses melting at low temperatures, rich in alkali, are better suited than hard glasses rich in silica'. The HLLA recipe, with a low level of potassium and high level of silica was therefore, probably, not favourable for the production of murrey glasses. Amber glass, on the other hand, favoured reducing conditions, generally higher temperatures and/or longer melts, and thus could easily have been made to an HLLA recipe. However, the amber colour could also be easily made by the glass painter in the workshop using silver stain painted onto the cheaper uncoloured glass.

9.5.2 Silver stain

Some colouration could be achieved using silver stain. At Hyde (C15e) and also at Rievaulx (C15c) the majority of the German HLLA glasses that are silver-stained have compositions with manganese decolourant and are colourless. As such the medieval glass painters were able to fully exploit the range of colours available using silver stain, from yellow to orange and brown. As shown in table 9.10 it is evident here that the glass painters in the 14th and 15th centuries

were not deterred by the naturally tinted green colour that characterised in particular English glass and also some earlier French glasses.

Table 9.10 Summary of glasses that are silver stained

Site	C14, no.	Provenance	Colour	C15 no.	Provenance	Colour Of Glass
ALCESTER	6	FR E	Pale green			
BARDNEY						
BORDESLEY				1	ENG ST	Pale green
HYDE	5	FR E	Pale green	11	GER C	Colourless & v. pale green
LOUTH PARK				2	GER C	Pale green
RIEVAULX				4	GER C	Colourless & v. pale green
WHITBY	3	FR E	Pale green	2	ENG ST	Pale green

The English examples of silver stain include one fragment from Bordesley decorated with an architectural design (B39) and two fragments from Whitby with unclear designs, but which may also be architectural (W13, W14). These glasses are significant because they were probably part of pictorial window schemes installed in the churches, possibly in the important west windows (see sections 5.5.3 and 5.5.7). Their use in these important windows may have involved factors such as cost, availability of the glass and logistics of transportation. At Bordesley (for the glazing episode dated around 1400), for example, French glass was possibly not readily available due to the Hundred Years War and the Black Death, and the use of German glass was possibly prohibited by the cost and logistics of transportation to Worcestershire. At Whitby, English glass was possibly used in glazing of the Great West Window, installed in the early 15th century. As with Bordesley, French glass may not have been readily available at this time and the large commission (that the west window would have been) may have required more glass than could be sourced from Germany. As described in section 5.5.7, Whitby suffered from storm damage and the reglazing of the huge Perpendicular replacement-window may have required additional supplies to supplement the German glass.

9.5.3 Summary of coloured glass

Coloured glass was consumed at all study sites, as might be expected in religious glazing schemes from the late 12th to the late 15th centuries (the single 16th century glass is uncoloured). The range of colours used included murrey, amber, blue, green and red. There are three types of red based on the method of their manufacture, and which therefore can be used to broadly date a glass. From the late 14th/15th the range of colours reduced to just red and blue, with a more limited use of green. The use of the colours according to the decoration shows that different colours were used for different decorative purposes: murrey was used for skin tone until the 14th/15th century when it was superseded by uncoloured glass; amber

was employed for grisaille and border patterns, and until the mid-14th century was used for Lombardic lettering; blue and red were used similarly for drapery and diaper decoration and green was used for foliate decoration. The use of these colours in this way has a long history, for example, red, blue and green were all popular in the biblical windows of the 12th century and they continued to be used for clothing and background patterns throughout the medieval period. Many of the colours were highly symbolic, red for instance represented the blood of Christ, the Catholic Church, power and martyrdom, and blue symbolised the divine, godliness and the Virgin Mary, and as such, conveyed the message of the bible at the abbeys through the vehicle of the stained glass window (see section 4.4.1). The east window at All Saints Church, York depicting the Annunciation (1320-40) is a fine 14th century example of figures within an architectural canopy, demonstrating the use of blue for the drapery of the Virgin Mary, green for the foliate-background and border patterns, and red and green for the drapery of the angel Gabriel (CMVA 005251).

The absence of amber glasses in the study may be explained by its replacement (by the glass painters) with silver stain painted onto colourless glass. Silver stain was cheaper than importing coloured glass, although still expensive (Westlake, 1882, p. 99), and was also quick to apply, would allow finer detailing and less lead came was required (see section 4.5). Although the technology for producing silver-stained glazing was available from the early 14th century, its use was more widespread in the later 14th and into the 15th century, concomitant with the increased use of colourless glass in glazing (see section 4.4.3)

All of the coloured glass in the study was imported, which correlates with the documentary and archaeological evidence that no coloured glass was made in England in this period (Marks, 1991, p. 30). Excluding the single 12th century murrey glass from Germany, all coloured glass until the mid-14th century has a French origin, thereafter, all production is German excluding two French glasses that were probably from stock and may therefore have an earlier date. As a result of the 14th and 15th century French hiatus in glass production and trade, two significant changes took place: there was a shift in the production of coloured glass to Germany and there was also an increased use of uncoloured glass coloured using silver stain.

9.5.4 English glass and colour

It is possible that English producers in the medieval period may have been disadvantaged in the market economy, particularly in the supply of glass for large glazing commissions because of their incapacity to produce intentionally coloured glass (as described above). Many continental producers, conversely, supplied both coloured and uncoloured glass for single glazing episodes. This is shown in table 9.11, where coloured and uncoloured glass together was supplied from over half of the continental sources. For the 14th century glazing episode at Alcester, for example, uncoloured glass and the full range of coloured glass (five colours) was supplied from the eastern area of France; and for a 13th century glazing episode at Rievaulx, uncoloured, and green and murrey glass was supplied from the north-central region of France.

Even in the 15th century, when uncoloured English glasses were consumed at the abbey sites, they were also supplied by continental producers. For the mid-15th century glazing episode at Hyde, glasses were sourced from Germany (C), which happened to have three different compositions and may have been supplied by different producers: C15c comprises all coloured glasses and C15d and C15e are both uncoloured. For an agent sourcing a large order of glass from a single production area, albeit possibly from multiple glasshouses, this may have been both efficient and profitable due to economies of scale, even with the high transportation costs. In this example from Hyde, English and French uncoloured glasses were also consumed. As discussed in 9.6.2, below, these glasses may have been used as a supplemental supply to the German imports of uncoloured (and coloured) glasses.

Table 9.11 Sources of coloured and uncoloured glass in the study

Source		Sub-band	No. uncoloured	No. coloured
	C12 soda			1
French	C13 NW	A1	11	6
	C13 NC	A2	5	2
	C14 NW	A3	15	1
	C13 NC	B	46	13
	C13 NC	C1	6	
	C14 NC	C3	2	3
	C15 NW	E1	4	
	C14 E	F1	39	16
	C14 E	F2		2
	C14 E?	F1/F2	2	
English	C14 ST	E ST	2	
	C15 ST	E ST	17	
	C14TW	E TW	5	
German	C13 GER	G A		1
	C15 GER	G B1	13	1
	C14 GER	G B2	2	1
	C15 GER	G C	52	16
TOTAL			221	63

Manufacturing coloured glass required knowledge of recipes and techniques, skill and experience and as mentioned it is possible that some continental glasshouses specialised in coloured glass production. This is suggested by the single 12th century murrey glass from Bardney (B18) and the abovementioned 15th century group from Hyde, both provenanced to Germany. Thus, English glassmakers may not have had the knowhow to manufacture coloured glass; nescience, or ignorance of techniques that might relate to the relatively closed nature of the English glassmaking industry. As discussed in section 2.8, glassmakers in England were organised into kinship groups following the family pattern of ownership. There was no glassmaking guild or apprenticeship scheme that encouraged the movement of the

glassmakers and the circulation of new ideas, recipes and techniques, thus the skills and knowledge required for coloured glass production may have been inaccessible – even though the glassmaking industry in England was likely established through the initial movement of continental glassmakers to England (see section 2.10.1). Equally, the English glassmakers may have accepted the status quo; glassmaking in England was at times sporadic and part-time, and investing time and money into new recipes and learning new skills may have been financially precarious. Vessel glass was also produced by the same glasshouses that made window glass (for example, Kenyon, 1967; Welch, 1997) and may have had an effect on the output of the English glasshouses to a single product, that of uncoloured glass. It is important to note that colourless English glass may have also been used in other types of glazing scheme, for example at high status residences, and English production may have been geared to a different, secular market.

9.6 Consumption choices

Much of the glass that was consumed at the monastic sites travelled long distances from glass production centres in continental Europe and areas of England. Glass was expensive to transport. Willmott (2005, p.45) identifies that transportation costs accounted for up to one sixth of the cost of the glass. As such, it might be expected that proximity to supply would be a major factor influencing what was used at each of the sites particularly with the involvement of profit-minded agents, merchants, and hauliers such as the Hanseatic League and the Company of Merchant Adventurers. However, other factors may have influenced the choice of glass supply including the colour of the glass and whether glass was available, sometimes in great volume.

This section will begin with an examination of consumption patterns of sites from the same areas and the influence of cost and ease of transport on glass source, before exploring whether religious order influenced the choice of supply and reporting on whether the source of the glass was dependant on how the glass was used; where it was installed and how it was decorated.

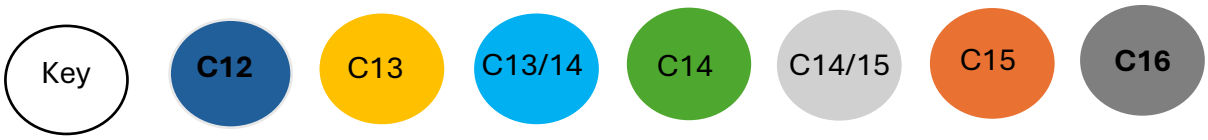
9.6.1 Consumption according to location and proximity to regional production centres

All of the glasses in the study from the late 12th to the second quartile of the 14th century were sourced from continent Europe. Established trade routes in France used the network of rivers to reach ports such as Rouen and Honfleur, while German glass was transported along the rivers Rhine and Meuse to ports along Germany's north coast. Transportation by water was probably cheaper and easier than by road, and sea and river routes could carry bigger loads more quickly with reduced breakages.

The initial destination of the glass would probably have been the glass painter's workshop. Finished glass panels were fragile and difficult to move safely and thus glaziers set up workshops close to the major (usually ecclesiastical) building works, for example in Lincoln, Coventry, York, Salisbury and Oxford, although glass painters were also peripatetic, moving between commissions (Marks, 1993, p. 40-42). These towns were well connected to ports and also inland (to Staffordshire, for example). Marks states that the supply of glass came from the nearest source, that York used German glass and Exeter used Normandy glass, for example, but in the later period, glaziers used glass from all areas. This is explored using the provenance of the glasses in the study.

Godfrey (1975, p. 200) provides details of the size of the consignments sold to the glaziers, although from the post-medieval period: crown glass was sold in cases of 24 crowns and broad glass was sold in cases of 60 sheets; 200 cases were in a lode. In 1400 Peter Shortere (from the Weald) supplied five lodes of glass to Westminster (that weighed 1200 lbs). As can be seen, these are sizeable amounts, and which perhaps accounts for the use of glass often from a single source in many of the glazing episodes in the study. At Alcester, for example, a single source was used for each of the glazing episodes between the 13th and the 16th centuries, and at Bordesley, a single source of English glass was used for the glazing episode dated around 1400.

The maps (figures 9.11 to 9.17) indicate the source of glass for each site. Coloured circles represent the different compositional groups, which are coloured according to the date range shown in the key (using the colour system that is used throughout this thesis). Trade routes are depicted in blue, signifying the general direction of maritime transport from the continent. The study sites are marked with an asterisk. The maps are arranged according to geographical area with one Benedictine (left) and one Cistercian monastery (right); thus, Alcester and Bordesley, Bardney and Louth Park, Whitby and Rievaulx, and Hyde separate as there is no Cistercian counterpart from the south coastal area.



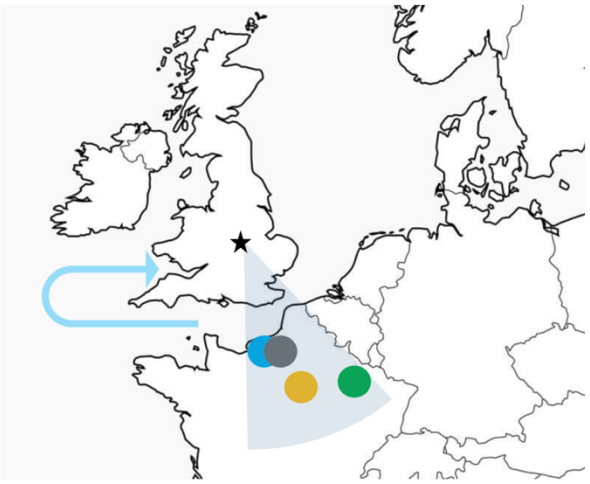


Figure 9.11 West Midlands: Alcester

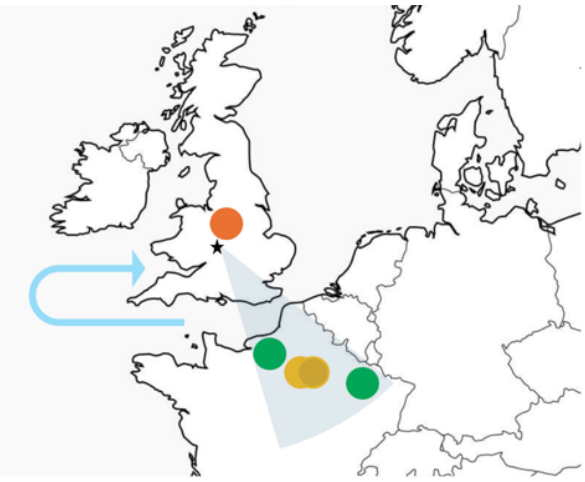


Figure 9.12 West Midlands: Bordesley

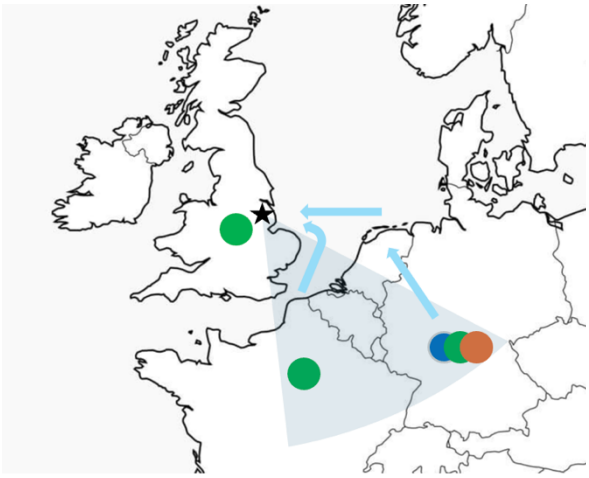


Figure 9.13 Lincolnshire: Bardney

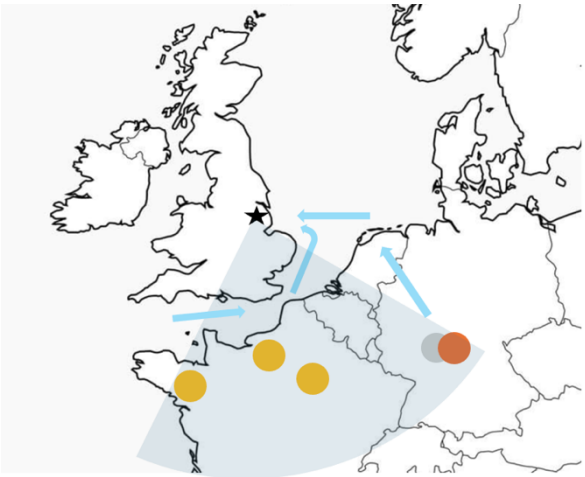


Figure 9.14 Lincolnshire: Louth Park

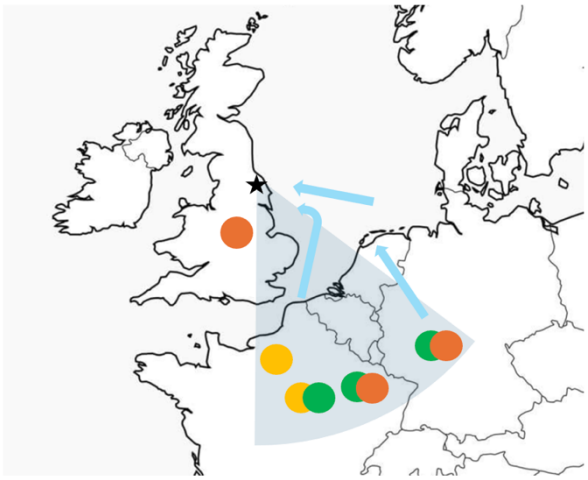


Figure 9.15 North Yorkshire: Whitby

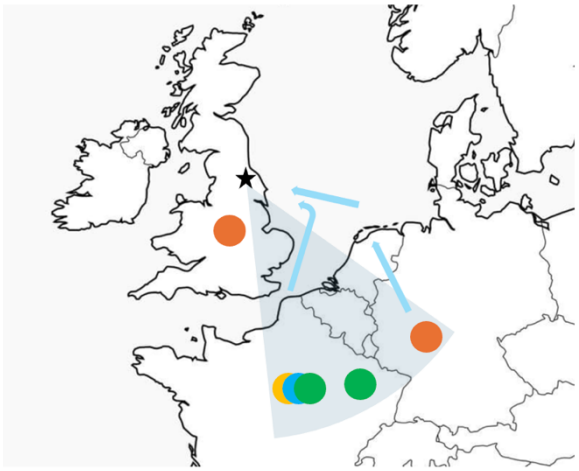


Figure 9.16 North Yorkshire: Rievaulx

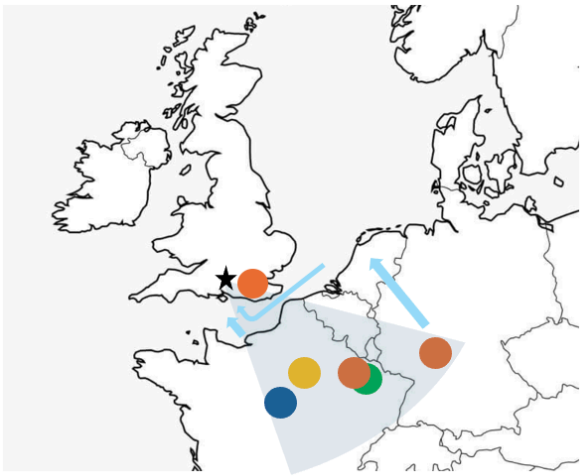


Figure 9.17 South coast: Hyde

As discussed in section 5.1, the seven sites in the study are located in four areas of England, the West Midlands, Lincolnshire, North Yorkshire and the south coast. There is a Benedictine and Cistercian abbey in three of the study areas, and one Benedictine abbey on the south coast. Each area has access to a different network of sea, river and road trade routes used to transport the glass. It could be assumed that the abbeys would choose the nearest suppliers of glass as a cheaper, easier and quicker option, as Marks (1993, p. 30) suggests; this is explored for each geographical area as follows:

West Midlands

The West Midlands were well placed for trade with France using the port of Bristol, and all glass consumed at Alcester is likely French, and at Bordesley all glass is likely French and English-Staffordshire. No German glasses were consumed at either site, which probably relates to the distances involved and the cost and logistics of transportation. Staffordshire glass was the sole supply for the glazing episode at Bordesley around 1400. It might be

expected that a French supply was sought, however, this glazing episode was during the French hiatus when political events effected a decline in French glassmaking and trade and German glass, as suggested, was expensive. The multiple find spots at the abbey shows that the glazing episode was a major commission and the cheaper English glass would have been an economical option. The river route from Staffordshire to the West Midlands passed near Coventry where the renowned glass painter John Thornton maintained a workshop and the glass may even have been painted here (Thornton had painted the Great East Windows at York Minster and Great Malvern Priory in the early-15th century).

Lincolnshire

Bardney and Louth Park in Lincolnshire had easy access using the east coast ports to Germany, and northern and north-central France. However, there are different consumption patterns at these two sites, despite the geographical proximity, some of which relates to differences in the date ranges of the respective glazing episodes.

In the 13th century, Louth Park consumed French glass only for a single glazing episode using glass from three different regions including Brittany. As discussed in section 5.5.5, in the early to mid-13th century Louth Park undertook an extensive programme of building requiring glass from a range of regional production centres. Transporting glass from Brittany was a long journey and would have been expensive, thus demonstrating the scale and perhaps pressing nature of the glazing commission, and also that cost was probably not a driving factor in the glass choices.

At Bardney, there was a preference for German glass: it was consumed in the late 12th, late 14th and mid-15th centuries and this is probably due to the proximity to the German glasshouses and availability of supply networks, and possibly also the use of a specialist glasshouse for the murrey coloured glass in the 12th century. German glass was also sourced for glazing at Louth Park but only from the late-14th to early 15th century during the French hiatus, thus availability was probably the key factor with this order.

The German connection was perhaps stronger at Louth Park as no English glass was consumed here. At Bardney, however, Staffordshire glass was used alongside German and French glass for the glazing episode that is dated to the 1330s, and this is the earliest use of English glass in the study. The German and French supplies included blue (German) and striated red glass (French), plus uncoloured. The English glass may have been sourced as an additional supply of uncoloured glass for what may have been a large glazing commission.

North Yorkshire

Whitby and Rievaulx were both well connected with the continent via east coast ports, and glass was sourced for both sites from all three French production areas, Germany, and Staffordshire in the 15th century. Neither site appears to favour particular sources of glass based on proximity, and perhaps French and German glass was equal in terms of transport costs and logistics. It can be seen that Whitby and Rievaulx are comparable in terms of consumption, and in the 1340s may even have used glass from the same consignment (see 9.7, below). Both sites used Staffordshire glass in the 15th century alongside German glass, some of which is coloured, and at Whitby also French glass, which is flashed red. Although of different dates both glazing episodes were major commissions, the glazing of the Great west Window at Whitby in the early to mid-15th century and the remodelling of the range at Rievaulx around 1490-1500, requiring multiple sources of glass - some of which was coloured, to meet demand.

South Coast

Hyde Abbey was close to the major port at Southampton and thus very close to France, and all glass consumed until the mid-15th century was sourced from the north-central and eastern regions. There was no glass sourced from northwest France despite this being the nearest French glassmaking area, although as discussed (e.g. in section 2.12.1.3) the other French regions were well connected to the northern ports. However, there may be other factors at play, perhaps the involvement of a glass agent working in the north-central and eastern regions. In 1446, multiple sources of glass were used for a single glazing episode when repairs were carried out following a fire. The glazing commission was significant since it used eastern French glass, Wealden glass, and three different compositions from Germany (C) including red and blue glass. The English glass is the only Wealden glass in the study. The change of source to predominantly German production is perhaps because of the desire for coloured glass, the source of which had shifted there during the hiatus in French production. The use of French, German and English uncoloured glass reflects the scale of the glazing commission. Thus, at Hyde, colour and availability were the driving factors in sourcing the glass, and perhaps the involvement of a dedicated regional agent.

9.6.2 Summary of glass consumption according to proximity to the glassmaking regions

The results show that the logistics and expense of transportation were significant factors in the source of the glass. This is evidenced at the two more westerly sites, Alcester and Bordesley, neither of which consumed any German glass throughout the study period. Price may have been a factor along with availability and speed of delivery as determined by proximity to glass production centres. As such, this may explain the prevalence of English glass in the 15th century.

For large and possibly pressing commissions glass was sourced from more distant glasshouses, from Brittany for example for the glazing at Louth Park in the 13th century. Goods from Brittany were imported into England through Bristol (Faith, 2012, p. 694; Miller, 1964, p. 27) and therefore, the use of glass from Brittany at Louth Park on the other side of the country is surprising and would have involved lengthy and expensive transportation. The consumption of glass from this source at Louth Park thus serves to highlight the scale of the building and glazing work in the 13th century, the level of investment in the project, the drive of the chief patron the Abbot Dunholme and the suggestion that availability of glass may have been a more important consideration than cost. At Hyde, the obvious nearby source from Normandy was not used at all and it is conceivable that the abbey or the glazier patronised other French areas through the conduit of a glass agent. Brown (2019, p. 10) describes how glaziers in the 16th century sourced ruby red flashed glass specifically for etching, and in the study, coloured glass was supplied from colour specialists, for example from German glasshouses in the 12th century at Bardney and in the 15th century at Hyde. The German glasshouses also supplied glass in volume for the large glazing episode at Hyde, here supplemented with English glass. The use of English glass coincided with the hiatus in French glass production in the mid-14th and 15th century, but during this period it was German glass that dominated the market, facilitated through good trade relations with England particularly, as shown in the study, the areas close to the North Sea coast and the Channel.

9.7 The source of glass according to religious order

The two contrasting orders, Benedictine and Cistercian differed in their principles and practices, and it might be expected that the consumption of glass also differed; this section considers whether monastic order had any effect on the source of the glass, its decoration and deployment.

The Cistercian order was controlled centrally by the mother house in Citeaux in the north-central areas of France, and the abbeys were regulated by a system of mutual supervision with strong lines of communication between houses. The unity, simplicity and standardisation that was apparent in the architecture and glazing of the 12th century was gradually abandoned in favour of more richly ornamented and sometimes sumptuous architecture and fenestration due to their increasing wealth (see section 3.8.1). Benedictine monasteries in contrast, were autonomous and self-governing religious houses although they shared a common bond of adherence to the rule of St Benedictine. This included a focus on scholarly and artistic pursuits, and the important Benedictine buildings were richly ornamented and fenestrated (see section 3.8.1).

Table 9.12 shows that in the period up until the mid-14th century both monastic orders patronised the same French glassmaking centres, in particular the north-central area. Here,

the glassmaking industry was stimulated by the construction and glazing of ecclesiastical buildings that included the Cistercian motherhouse at Citeaux between 1140 and 1193. It is possible that the procurement of window glass for the Cistercian daughter houses was organised by Citeaux, in keeping with the Cistercian system of centralised regulation. However, as shown in table 9.12, there is a similar pattern of consumption at the more autonomous Benedictine houses; clearly, this glassmaking area was the favoured source for both orders. For the Benedictines, procurement may have involved a glass agent; monastic agents are known to have worked for English monasteries, including the Cistercians in the sale of their wool to the European market (Faith, 2012, p. 694) and it is possible that a glass agent also arranged the procurement of the glass to the Cistercian houses.

Table 9.12 The consumption of glass from different sources according to religious order

Date range	Site	Date (order)	French regions			German	English	Key
C12	Hyde	l. C12	Soda					
	Bardney	l. C12				A		
C13	Whitby	1220-35	NC	NW				Benedictine
	Alcester	c. 1238	NC					
	Hyde	e-m. C13	NC					
	Bordesley	e. C13	NC					
	Rievaulx	1220-39	NC					Cistercian
	Louth Park	1227-m. C13	NC	NW				
	Bordesley	l. C13	NC					
C13/14	Alcester	C13/14		NW				
	Rievaulx	C13/14	NC					
C14	Whitby	1310-25	NC					
	Whitby	1333-38	NC		E	B		
	Alcester	2nd quartile			E			
	Hyde	m. C14			E			
	Bardney	c. 1340	NC			B	ST	
	Bordesley	e. C14		NW	E			
	Rievaulx	1340s	NC		E			
C14/15	Louth Park	C14/15				B		
C15	Bordesley	c. 1400					ST	
	Whitby	c. 1410			E red	C	ST	
	Bardney	1437-38				C		
	Hyde	c. 1446			E	C	TW	
	Louth Park	m. C15				C		
	Rievaulx	m-1500				B, C	ST	
C16	Alcester	c. 1515		NW				

In the 14th century both orders maintained their patronage of the north-central glasshouses and also used a new source of glass from eastern France. At Rievaulx and Whitby, glass from this source, with a comparable composition and therefore possibly from the same consignment was supplied for glazing episodes that are both dated to around the 1340s. This could suggest that the two contrasting orders (or the glaziers or agents working on their

behalf) had co-ordinated their glass-buying. Both groups of naturally coloured glass are the same pale green although the Rievaulx glasses, which have evidence of broad production, are slightly thicker, 3.2 mm on average compared with 2.1 mm at Whitby. Although for the most part the range of motifs used for the two glazing episodes is different, both have similarly painted border fragments with a linear stickwork design (R20, W11) (figure 9.18). Whether the same glass painter was employed is unknown but perhaps the same source buildings was consulted in the design process (see section 3.8.2). It should be noted however, that stickworked motifs such as these were not uncommon. Nonetheless, these examples highlight the potential influence of the glazier and of source buildings in the choice of glass design and possibly glass source, regardless of monastic order.

Figure 9.18 Illustrations of linear stickwork decoration of R20 from Rievaulx, left, and W11 from Whitby, right, showing the similarity of the decoration from both sites

From around 1340, German glass was used by Benedictine sites, and from the late 14th to early 15th century by the Cistercian sites. Glass from eastern France continued to be used by both orders, and glass sourced from England was first used at the Benedictine site of Bardney. In the 15th century both orders consumed English and German glass.

Overall, there seems to be little difference in the origin of the glass used by the two contrasting monastic orders. Only Cistercian Louth Park patronised Brittany in the 13th century and as suggested for the north-central area, a glass agent may have been used. For all sites, it is possible that the glass painters or a glass painter's guild may have been influential in the source of the glass. In the late 15th century, the glass painter's guild of Antwerp stipulated that alongside locally produced glass, only the higher quality Norman crown glass be used by its members even though it was the most expensive (Caen, 2009, p. 236). Glass painters' guilds were in existence in England from the 14th century although it is unknown whether their role was to control the source of the glass used by the glazier (see section 4.5.1).

9.7.1 Use of decorative glass according to religious order

This section will discuss the use of glass by the two different orders according to the range of decorative patterns and motifs painted onto the glass and the location of the windows that the fragments might have been part of.

Table 9.13 and 9.14 show that both orders use a similar repertoire of motifs and decorative patterns. However, there are no heraldic devices at the Benedictine sites although the lettering (at Hyde) may represent the name of a donor or a date of marriage, for example at Bardney Abbey, where a donor window was installed in the refectory in 1379-83 (Brakspear, 1922, p. 36). Both orders also used plain glass and a comparable range of coloured glasses although there are no 15th century green glasses used at any of the Cistercian sites.

Table 9.13 Decorative patterns at Benedictine sites. Stiff leaf grisaille is abbreviated to SLG

Benedictine	Applied decoration	Colour	Installation
C12	Drapery	Blue	Abbot's lodgings, refectory
C13	SLG, lettering	Amber, red, blue	Chapter House
C13/14	Grisaille		Chapter House
C14	Figural, background diaper, grisaille, border	Full range, silver stain	Chapter House, refectory, abbot's lodgings
C15	Figural, background, micro-architecture, lettering	Red, blue, green, silver stain	Abbot's lodgings
C16	Lettering		Chapter House

Table 9.14 Decorative patterns at Cistercian sites. Stiff leaf grisaille is abbreviated to SLG

Cistercian	Applied decoration	Colour	Installation
C13	SLG, grisaille, foliate	Blue, green, red, amber, murrey	Church, Chapter House,
C13/14	Grisaille	Murrey	
C14	Grisaille, background diaper, heraldic, micro-architecture, border, figural	Amber, blue, green, red	Church, Chapter House
C14/15, C15	SLG (replacement), border, figural, micro-architecture, lettering, background diaper, border, heraldic	Blue, red, silver stain	Church, west range, gatehouse chapel, west range or cloister

Another point of interest is that there are few coloured fragments (only four out of 49) and a limited range of decorative elements at Louth Park (figure 9.15). The glazing scheme represented by these glasses may be an example of the overall monochromic simplicity that characterised particularly early Cistercian window decoration.

Table 9.15 Decorative patterns at Louth Park. Stiff leaf grisaille is abbreviated to SLG

Louth Park	Applied decoration	Colour	Installation
C13	SLG, lettering	Amber, red	Unknown
C14/15	SLG (replacements), border motifs	Red	
C15	Figural, architectural, lettering	Blue, silver stain	

A comparison of the location of the window installations in the study is somewhat limited by the lack of find spots in common, the Chapter House being the only building where the study glasses from both orders were used. However, there are few fragments that match date-wise to make an informed judgement. Nonetheless, the range of buildings represented by the glasses for both orders are some of the key buildings in the complex. It would be expected to find the best window schemes in these locations, and also where the donor windows would have been installed (particularly in the church). As discussed above, there appears to be no huge difference between the orders in the use of glass, except for, perhaps the restrained scheme at the Cistercian abbey of Louth Park. The scheme may have been a choice in accordance with Cistercian rules of simplicity, but it is also possible that the use of cheaper, predominantly monotone glass may have been a financial decision; the glass was widely sourced and probably expensive to transport.

The religious houses of both orders were sometimes located in close proximity to each other, in the Witham Valley in Lincolnshire for example, where the fertile land and wealthy patrons supported nine monasteries that included Bardney and Louth Park. For these abbeys, there may have been a strong influence of source buildings from which ideas about the theme of a window or design details may have been copied. There may also have been shared glass painters working in local styles. The influence of source buildings and the glass painter may be supported by the example in the study discussed above where glasses from Rievaulx and Whitby have a similar composition and may have been painted by the same glass painter.

9.8 Comparison of consumption of glass of different origins

This section discusses the consumption patterns of glasses from different countries of origin, examining the location of the fenestration in the abbey, the style of the applied decoration and the type of window scheme that the glasses may have been part of.

9.8.1 Location of glazing in the monastic buildings

French glass was installed in the main buildings on the monastic range, including the church, Chapter House and refectory, and buildings in the west range that could include the frater; German glass was installed in the church, refectory and abbot's lodging; and English glass was also used in some of the key monastic buildings, including the church, refectory, the abbot's lodgings and buildings in the west range of the complex. English glass was also, probably used in some of the most important windows, for example the Great West Window at Whitby and probably also at Bordesley. Thus, glasses from these three countries of origin were all used similarly, in key windows in key buildings in the monastic range.

9.8.2 Decoration

A summary of the applied decoration, colours and possible window schemes using French, German and English glass is shown in tables 9.16 to 9.18. It can be seen that glass from France and Germany was used in figural or narrative schemes in the 12th, the 14th and the 15th centuries, when there are depictions of hands, feet and faces and drapery. Many of the glasses are coloured, for example, both 12th century glasses (blue and murrey), and much of the French 14th century glass; there is a larger range of colours with the French glass (see 9.5.1 above).

Table 9.16 Decoration applied to French glass

Date range	No. (174)	Applied decoration	Window scheme	Colours
C12	1	Drapery	Figural / narrative	Blue
C13	74	Stiff leaf grisaille (SLG), lettering	Grisaille and biblical schemes	Amber, red, blue, green, murrey
C13/14	3	Naturalistic grisaille, foliate	Possible figural window scheme	Murrey
C14	90	Border and background motifs, lettering and architectural motifs	figural-architectural	Full range of colours amber, red, blue, green, murrey, silver stain
C15	5	Figural	Figural	Red
C16	1	Lettering	Possible donor window	Uncoloured

Table 9.17 Decoration applied to German glass

Date range	No. (86)	Applied decoration	Window scheme	Colours
C12	1	Possibly figural	Biblical	Murrey
C14	4	Figural, border patterns	Figural	Blue
C14/15	12	Border, SLG	Replacement SLG	Red
C15	69	Background, border, micro-architecture, lettering, figural	schemes with a figure depicted in an architectural context	Blue, red, green, silver stain

Table 9.18 Decoration applied to English glass

Date range	No. (24)	Applied decoration	Window scheme	Colours
C14	2	Border and background patterns	Possibly part of a figural window	
C15	22	Figural and architectural motifs, and border and background patterns	Schemes with a figure depicted in an architectural context	Silver stain

Other than at Bordesley in the 15th century, all English glass was used alongside French and German glasses in the same glazing schemes. In the 14th century the two glasses from Bardney are border and background motifs and may therefore have played a more 'supporting role' to

the main figure, often a saint or an abbot in a typical 14th century scheme. As described in section 4.4.3, 14th century windows were very colourful, particularly the drapery and thus the colourless English glass at Bardney may have had limited uses in such schemes. The 15th century English glasses from Hyde and Whitby are decorated with micro-architecture, lettering and foliate motifs, some of which is silver-stained, and again, these glasses may have only been used for the background, although, in a very tall, 15th century Perpendicular window this would have been an expansive area. Nonetheless, the limitation of the colourless or at best silver-stained English glass may have prevented its use, at least at Hyde and Whitby in depicting the main figure of a typical 15th century window.

At Rievaulx the English glasses are painted with lettering and foliate motifs, but also there is one fragment that depicts a face (R23). By this period uncoloured glass was used for skin tone (see section 4.4.4) and the German glasses from the same glazing episode carry a similar range of decoration, although one glass is flashed red. This demonstrates that for the glazier making up the window, other than the deployment of the coloured glass, perhaps there was little difference in how the German and English glasses were deployed in the window, or that a difference in the source of the glass (and perhaps its appearance) was not considered important. The glazing scheme at Bordesley, which in the study is represented only by English glasses, similarly comprises a figural element, here a depiction of feathers probably from an angel. The single silver-stained glass (B39) shows that some colour was used albeit from a palette restricted to the colours of the silver stain repertoire. B39 is one of three English glasses that are silver-stained, out of 24.

9.9 A summary of English glass consumption

There are no English glasses in the study until the first half of the 14th century. The industry at this time was in a development stage: the earliest evidence of glassmaking in the Weald is around the mid-13th century and in the 13th/14th century in Staffordshire. Even so, there is scant evidence of the consumption of English glass in this period - possible glazing at Westminster around 1240, then nothing more until the mid-14th century at the royal chapels at Westminster and Windsor, although there is tentative evidence from Eynsham Abbey to the 13th/14th century (Paynter and Doonan, 2002). The English glassmakers also made vessel glass and had probably been supplying glazing to local churches during this period, although records are meagre. One example is the late 14th century window at St Marys in West Horseley, Surrey (figure 9.19) that Baker (1978, pl. 40) believes is English, based on green tint (as per Gloucester Cathedral, see below) and the close proximity of St Marys to the Weald.

Figure 9.19 Late 14th century window at St Marys in West Horseley, Surrey that Baker (1978) believes is English (www.stmaryswesthorsley.co.uk/aboutus/church-history, 2024)

In the study, the 14th century English glass comprises just two samples from Bardney, but in the 15th century, English glass was consumed at five of the study sites. As discussed, many of these 15th century glazing episodes were large and English glass, and probably also the small amount of French glass that was possibly from glaziers' or warehouse stock, may have been used as a supplemental supply to the German imports of both coloured and colourless glass. At Hyde the English glasses comprise 17% of the total of the 15th century glazing episode, and at Rievaulx this figure is 26%, which is not an insignificant amount. At Bordesley, English glass was used exclusively for the 15th century glazing episode that, as discussed above, may be explained by the expediency of English glass supply as much as the logistics and expense of importing German glass to the West Midlands, if it was even available.

Glass made in England in the 15th century had such a poor reputation that the glazier, John Prudde was told not to use it for the glazing of Beauchamp Chapel in Warwickshire in 1447

(Marks, 1991, p. 266). It might be assumed, therefore, that English glass would not be used in the key monastic buildings, particularly the church. However, as shown, English glass was used in key buildings. The question then is why was it used if its quality was supposedly so poor? Knowles (1922, p. 352) states that in the context of the Black Death English glass was used because 'it was available', using the example of Gloucester Cathedral, which was glazed with predominantly uncoloured glass in the early 15th century and to which Knowles assigns an English provenance based on its green tint (as per Bordesley). Many late 14th and 15th century windows are characterised by the expanse of uncoloured glass, smaller areas of colour, predominantly blue and red, and highlights of yellow and earthy colours created using silver stain. Examples include St Martin, York (CVMA 18153), Great Malvern Priory (CVMA 10973) and Margaretting (CVMA 25262). This style was born out of necessity when coloured glass supplies were interrupted in the 14th century but was also a cheap option - panels that used fewer coloured quarries and more silver stain required less leading and parsimony may have maintained its popularity even when supplies of coloured glasses were resumed. English glass was also cheap; purchase records show that in the mid-14th century, English glass was around a third cheaper than continental glass (Marks, 1993, p. 31). There was increased demand for window glass during the 15th century religious revival when patronage funded the remodelling and repair of monastic buildings that included the provision of new windows. The 'cheap and available' English glass, which could be coloured using silver stain and was at times comparable in quality to some of the continental glass (for example at Whitby), is shown in the study to have been used in some of the glazing commissions.

Although the group of English glasses in the study is small (24 glasses of a total of 284 (8%)), it is nonetheless able to show when, where and how it was used at the abbey sites. Some of the glasses from Bordesley and probably also Whitby were retrieved from the west end of the church and were possibly part of their respective Great West Windows. These were extremely important installations and the use of English glass here is noteworthy - far from being 'crude forest wares' (Kenyon, 1967, p. 13) and of 'indifferent' quality (Marks, 1993, p.30), the English glass used for the west window at Whitby is mostly thin, flat and smooth. One sample (W13) shows evidence of broad production (see figure 7.35, section 7.8.3) and another sample (W20) is even repaired using shellac (figure 9.20, left and right), perhaps demonstrating its value to the abbey and that it was worth repairing. The use of English glass here, at Whitby, as well as Bardney, Bordesley, Hyde and Rievaulx demonstrates that English glass, although not used in great quantities, was of a sufficient quality to be included in the great windows of some of the most important buildings at monastic sites in England.

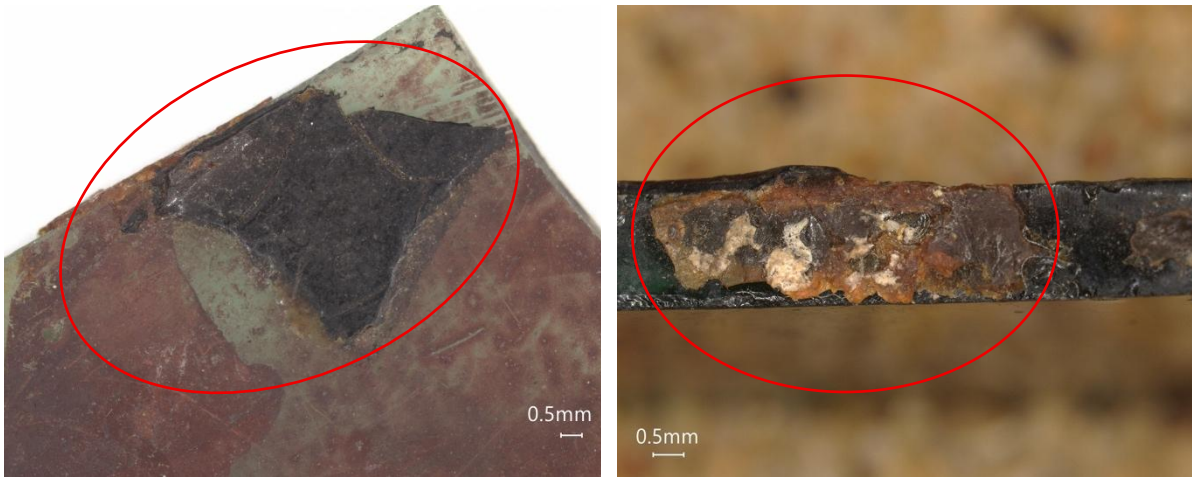


Figure 9.20 W20 shellac repair, plan and section

Chapter 10

10 Conclusions

10.1 Aims of the study in context

The purpose of the study was to examine the consumption of English window glass at high status sites, using a case study of excavated window glass dated from the 12th to 16th centuries from selected Benedictine and Cistercian abbeys across England.

The aims of the study were to:

- identify and date glazing episodes at each site
- to characterise the glasses physically
- to establish the source of the window glass used at monastic sites in England using data obtained from a chemical analysis, and investigate how this changed over time
- to interpret the results in the context of the social, political and economic background to the period, and establish the factors that influenced the choice of glass source
- to use the results to analyse the complexities of the glassmaking industry in window glass production in England and compare these with the continental glasshouses.

The study has been an extensive, multi-analytical and interdisciplinary study of 284 unpublished, excavated fragments of window glass from seven monastic sites in England. Previous consumption studies show that window glass made in England was sometimes used at high status sites, although evidence is scarce and limited to individual sites. The benefits of a wider study, therefore, are that systems of glass consumption can be shown and interpreted against a changing historical backdrop. The large compositional data set was acquired through the use of micro XRF, which was a rapid and largely non-destructive analytical technique. The glasses were characterised physically using macro and microscopic techniques, and the tight-dating of the excavated fragments was achieved through established art-historical techniques combined with new techniques developed for this study.

10.2 Archaeological conclusions

- All glasses in the study were found to be sourced from France, Germany and England, and there are no glasses with a central European origin

- Glazing episodes at the abbeys fluctuated with the flow of income and a hiatus in glazing coincided with periods of poverty and the Black Death. Where glazing was

undertaken during known periods of poverty, it is suggested that these were donor windows.

- French glass dominated use at all abbeys in the early period, but the Hundred Years War and the effects of the Black Death in the 14th and 15th centuries stifled glassmaking in France, patronage then shifted predominantly to German glasshouses.

- English glass was first used in the first half of the 14th century and throughout the 15th century. Prior to this the English industry was in a development stage and small scale, and glass for glazing may not have been available prior to this date. The earliest evidence of glassmaking (and possible use) is dated to around the mid-13th century, with further evidence in the mid-14th century, although evidence for its use is scarce.

- Proximity to glassmaking centres was a major factor in choosing the source of the window glass used at the abbeys, although this was not the only factor. Other considerations included availability (particularly for glass that was bought in bulk), price, and the proclivities of glass agents who may have liaised between favoured regional glasshouses and the client. Glass was expensive to transport and in general the abbeys in the east of England favoured German and Staffordshire sources, and those in the west favoured French and Staffordshire sources. The sole site close to the south coast, Hyde, used French and German glass and was the only study site to use window glass made in the Weald. Surprisingly, the monastic order made very little difference to the source of the glass and for the most part, despite their different doctrines, both Benedictine and Cistercian abbeys concomitantly patronised the same regions.

- The glasses were retrieved from the key buildings in the nucleus of the monastic complex: the church, refectory, Chapter House, abbots' lodgings, and structures in the west range that may include the cloister. It seems that there was no difference in the use of French, German, and English glass in terms of which monastic building the glass was installed in. Where contextual information is available, glazing is shown to have been undertaken at multiple locations in the monastic complex concurrently.

- All of the English glass is uncoloured. An important finding from the study is that English producers limited their market appeal because of their failure to produce coloured glass (whether through choice or a lack of knowledge), while the continental producers could supply both coloured and uncoloured. This resulted in a more restricted range of decorative elements applied to the English glasses, and the majority of English glasses are used in border and background designs. Continental coloured glass could be used more widely, for example, for the brightly coloured figures popular in the 14th century.

- The increased use of English glass coincides with the creative overhaul of the late 14th and 15th century when windows comprised a greater area of colourless glass and an increased use of silver stain, which exploited the range of earthy colours that could be produced more economically. The increased demand for window glass during this period was exacerbated by a religious revival, and the fashion in religious buildings for very large, Perpendicular windows.

- Of significance is the use of English glass in the very important 15th century Great West windows at Bordesley, and possibly also at Whitby. English glass at this time had a poor reputation, yet its use in these windows demonstrates that it was regarded as being of a sufficient quality, or perhaps, it was a case of 'Hobson's choice' in terms of what was available for the budget. German glass from this period was generally colourless, broad-produced and of an even thickness. While English glass remained tinted green, it was fairly thin and smooth, and at Whitby the evidence for forming technique shows that it was broad-produced.

- The exclusive use of English glass for an extensive glazing episode at Bordesley Abbey around 1400 that includes the abovementioned west window, demonstrates how colourless and silver stained glass could act as a substitute for imported coloured glass. This could have created an opportunity for English glassmakers, although the dominance of German glass in the 15th century and the continued small-scale nature of the industry (Kenyon, 1967, p. 13) suggests it was probably not taken, or that the competition was just too great.

10.3 Methodological conclusions

The study has demonstrated the value of a multi-analytical, multifaceted approach to understanding the consumption patterns of window glass at high status monastic sites, which includes the use of English glass in the 14th and 15th centuries. The composition of forest glass in particular makes it prone to corrosion and this can be an obstacle to a study of excavated glass. The use of photography to reveal obscured decoration and computer-aided mapping to draw, quickly and accurately each fragment, created clear and detailed images of the decoration to use in the dating. These were simple and relatively quick techniques that required minimal equipment, and the quality photographs and illustrations may be a valuable addition to the corpus of decorated medieval glass. The Evidence Informed Dating Framework (EIDF) proved effective in fine-tuning the dating of the glasses by aligning glazing episodes with relevant, site-specific, documented building phases, window installations and events. The technical analysis used macro and microscopic techniques to characterise the glasses physically, making particular use of the Keyence digital microscope to examine the fabric of the glass to inform, for example on workshop practices. Micro XRF has been a suitable

analytical technique for rapidly and largely non-destructively analysing a large quantity of glass. However, the use of a surface technique meant that correction factors needed to be applied to eight elements (of 22). The micro XRF results were validated by SEM-EDS although sodium was poorly characterised under 2%. The study used major elements in particular potassium, calcium and manganese to distinguish compositional groupings and determine provenance where possible using scatterplots in tandem with principal component analysis (PCA).

10.4 Further work

The study has been successful in distinguishing and dating English window glass, and future work might apply the methodology to the glazing of other building types to investigate further the use of English glass in the medieval and post-medieval periods. This might include researching church windows, for example the late 14th century windows at St Marys in West Horseley, Surrey, that Baker (1978, pl. 40) believes contains English glass. The success of the current study is in part due to the amount of research material made available through the deconstruction of the windows in the Dissolution and as such is a unique source. Nonetheless, there are several assemblages of window glass from churches, castles and manor houses in English Heritage and museum archives that could be investigated to see if the pattern of use changes between religious and secular high status buildings. The beauty of the methodology is that it is largely non-destructive, and custodians of window glass may thus be encouraged to loan their collections for analytical study.

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Appendix

APPENDIX 1

Spectrum	
Alc 5	Curling side-facing trefoil with cusped lobes on a cross-hatched ground
Alc 6	Curling stem with five berries and no leaves with strapwork on a cross-hatched ground
Alc 12b	Curling stem on a cross-hatched ground
Alc 14	Lobe and partial lobe with curling stem on a cross-hatched ground
Alc 18	Double line border set on a cross-hatched ground with a partial lobe
Alc 20	Three branching stems on a cross-hatched ground
Alc 88	Upright partial trefoil with pointed cusp, curling stem on a cross-hatched ground
Alc 65A red	Roundel with three lobed grisaille in reserve on a plain ground with curving double line border
Alc 44 amber	Lombardic letter 'm' in reserve
Alc 46 amber	Lombardic lettering 'ex', as part of Rex
Alc 47 amber	Lombardic lettering 'hiAs' in reserve
Alc 73C amber	Running serpentine border pattern
Alc 0742 plain	
Alc 0748 plain	
Alc 0897 plain	
Alc 93	Partial upright naturalistic leaf with veins on thick and thin outward curving lines
Alc 74	Face of demon / grotesque in reserve
Alc 76	Rinceau pattern in reserve
Alc 79	Partial possible grotesque with tail in reserve
Alc 86	Partial fringed leaf in reserve
Alc 90	Right-hand side of figure in orans posture, in reserve, stickwork background of circles
Alc 91	Roundel showing foliate design in reserve with fringed edging, and 9 berries
Alc 49 blue	Rinceau pattern of quatrefoils in reserve
Alc 53 green	Quatrefoil in outline on plain ground with one pointed leaf, thick and thin edging
Alc 57b green	Foliate design with fringed edging in reserve
Alc 60 red	Rinceau pattern in reserve
Alc 61 striated red	Curved acuminate shaped quarry with indistinct banding
Alc 68 amber	Border pattern of leaf edges outlined on a plain ground with thick line borders
Alc 75 murrey	Forward facing face with cascading hair, large and rounded eyes, and well defined eyebrows, nose and mouth
Alc 41 SS	Curved stem highlighted with silver stain
Alc 41a SS	Possible foliate design on plain ground with two thin curving lines and serpentine/dotted border pattern in reserve
Alc 42 SS	Partial oak leaf in outline on plain ground with cross hatching and serpentine/dotted border pattern in reserve
Alc42b SS	Demon head with curling tail coloured with silver stain
Alc 80 SS	Possible rinceau pattern inreserve
Alc 92 SS	Partial oak leaf in outline on plain ground with cross hatching
Alc 0898 plain	
Alc 43	Letter m? 'Psalterium' font

APPENDIX 2

Spectrum	
Bard 18 murrey	Possible figurative / drapery detail
Bard 6	Diaper background or border pattern of floral morifs divided into three lobes in reserve with serpentine fill
Bard 11	Grisaille, quatrefoil motif depicting oak leaves in outline with central rosette and strapwork edging
Bard 4	Section of serpentine / dotted pattern with thick linear edging
Bard 13	Section of possible edging pattern
Bard 23 plain	
Bard 5	Background or border pattern of curves and dots in reserve with perpendicular strapwork
Bard 2 striated red	Narrow, linear border pattern in outline with internal dots
Bard 22 plain	
Bard 14	Possible foliate in reserve with scratched detail
Bard 7 blue	Diaper of stem and curving lobe in reserve with cross-hatching
Bard 8 blue	Diaper of upright stem amd lobe, in reserve with cross hatching
Bard 25 green	Indistinct pattern
Bard 24 blue plain	
Bard 21 plain	
Bard 1	Diaper pattern of curving trefoil or clover in reserve with scribbled background fill
Bard 9	Floral motif of stems and buds in reserve
Bard 15	Possible architectural detail, stipple shaded
Bard 16	Possible architectural detail of curved and straight lines, stipple shading
Bard 20	Possible architectural detail, stipple shaded
Bard 3 flashed red	Cross-hatching, possible border design
Bard 10 blue	Seaweed rinceau in reserve

APPENDIX 3

Spectrum	
B1	Lobe and partial lobe
B2	Partial cusped lobes from middle stem of a larger fragment showing radiating side-facing trefoil heads with single berry on a cross-hatched ground
B5	Partial open beading in reserve from larger fragment showing curved open beading border with quatrefoil set on a cross-hatched ground
B7	Cross-hatched ground with partial thick painted lines of an indeterminate pattern
B8	Stiff leaf veined stems with trefoil terminal and fruiting leaves on a cross-hatched ground
B17	Open beading border pattern
B18	Open beading with single line border on a cross-hatched ground
B46M green	Partial roundel of possible cinquefoil in reserve
B36 blue pl	
B12	Apex of quarry with strapwork edging
B16	Partial fruiting leaf in outline
B20	Quatrefoil flower head in reserve, part of diaper border pattern
B24	Apex of quarry with top half of fleur de Lys in reserve
B29	Detailed architectural tracery
B33	Grisaille, strapwork
B37	Curved banding with fringing possibly denoting foliage, as B38
B38 amber	Fringing possibly denoting foliage, as B37
B44	Grisaille quatrefoil quarry with pointed lobes and strapwork edging
B10	Cross-hatched curving stems with partial leaves on plain ground
B27	Architectural detail of towers in reserve
B28 blue	Drapery from probable chest area with suggestion of a hook folds
B41	
B42 bulls eye	
B43	
B11	Cross-hatched crossing stem on plain ground
B14	Multi-veined vine leaves on plain ground, as BO15
B15	Multi-veined vine leaves on plain ground, as BO14
B30	Detailed architectural tracery
B47M	Lower half of fleur de Lys in reserve
B23 yellow	Diaper pattern of partial maple leaf in reserve
B35 blue	Possible architectural detail
B40 flashed red pl	Border pattern of circles and lines in stickwork
B19	Stickworked cross diaper of circles and squares
B21	Seaweed rinceau background in reserve
B26	Partial feathered figure, probable angel
B31	Architectural detail of stipple-shaded masonry
B32	Stipple shaded architectural detail
B45M	Floral/shield centre boss
B48Mb	Architectural detail of crockets
B39 SS	Architectural detail with silver stained detail

APPENDIX 4

Spectrum	
H41 blue	
H18	Partial lobes on a cross-hatched ground
H15	Double line border
H17	A crude upright trefoil on thick cross-hatched ground
H19	Indeterminate grisaille design on a cross-hatched ground
H31	Oak leaf in outline with internal veins
H32	Tapering quarry with vegetal leaf with internal midribs in reserve
H52	Fragment of black letter / Gothic inscription '
H14	Architectural detail of picture window showing cross-hatching to denote glazed quarries
H56	Trefoil terminal cusp with silver stain highlight
H65	Oak leaf in outline with internal veins ans silver stained highlights
H85	Open beading in silver stain with parallel banding to rounded quarry edge
H87	Architectural detail highlighted with silver stain
H197 p	
H251 p	
H253 p	
H255 p	
H256 p	
H53	Black Gothic inscription '..jou..'
H55	Possible architecturall crockets
H57	Foliate or architectural finial
H82	Stipple shaded detail of architectural canopy
H89	Tesselated floor tiles in geometric pattern
H54	Letter 'M'? In Old English / Gutenberg style
H59	Foliate detail in reserve with internal veins
H102 p	
H91	Tesselated floor tiles in geometric pattern
H6 red	Lobed diaper pattern, as H8
H8 red	Lobed diaper pattern, as H6
H9 red	Diiper, vegetal design in reserve with tapering, internal vein, possibly seaweed
H43 blue	Diiper, vegetal design in reserve with tapering, internal vein, possibly seaweed
H46 blue	Dlobed daper pattern, as H47, H49
H47 blue	Dlobed daper pattern, as H46, H49
H49 blue	Dlobed daper pattern, as H46, H47
H27	Diaper or drapery foliate pattern in reserve
H92	Tesselated floor tiles in geometric pattern
H72	Crude flower pistil with silver stained highlights
H75	Indistinct silver stained motif, possible clothing detail
H79	Architectural detail of masonry, with solver stained highlights
H84	Possible architectural picture window detail
H50	Partial black Gothic letter
H69	Rosette border patterm with strapwork edging, as H70
H70	Rosette border patterm with strapwork edging, as H69
H71	Open beading in silver stain with parallel edging
H74	Indistinct motif with scratched detail and silver stain
H76	Detail of architectural arch with silver stained highlights
H81	Silver stained architectural crocket detail
H84a	Partial architectural picture window detail

APPENDIX 5

Spectrum	
L1	Crude upright trefoil with curling stem on a cross-hatched ground
L6	Curling stem with partial lobe and pointed spur on a cross-hatched ground
L9	Partial lobe on a cross-hatched ground with curved double line border. Part of a circular panel
L11	Outward curling stem with simple side-facing foliate motif on a cross-hatched ground
L12	Curling, possibly split stem on a cross-hatched ground
L13	Outward curling stems with simple side-facing foliate motifs, one in reserve and one partial motif on a cross-hatched ground
L16	Open beading border
L18	Open beading border
L35	
L36	
L2 same	Side curling foliate with two partial lobes on a cross-hatched ground
L5	Side facing trefoil head with pointed spurs on a cross-hatched ground
L7	Curving stem and partial cluster of four berries on a cross-hatched ground
L8 same	Radiating stems either side of trefoil head on a cross-hatched ground
L10	Partial cluster of five berries on a cross-hatched ground
L14	Two partial lobes on a cross-hatched ground
L19	Open beading in reserve with internal dots
L26	Lombardic letter 'C' in reserve
L43	Cross-hatched background with two partial probable foliate lobes
L44	Cross hatching with a single line border
L32 striated red pl	
L33 amber pl	
L3	Two partial trefoil leaf terminals with spurs on a cross-hatched ground
L4	Partial trefoil terminal with possible spur on a cross-hatched ground
L15	One half of a trefoil head with smear shading on a cross-hatched ground
L20	Repeating looped border pattern in reserve
L21	Running line border pattern with single line border
L22	Running line border pattern with single line border
L40	Cross hatching
L41	Cross hatching
L42	Cross hatching
L31 red pl	
L39	
L734	
L806	
L822	
L23	Possible architectural canopy detail
L24	Partial black Gothic letter
L25	Partial black Gothic letter, possibly 'F'
L27	Stipple shaded architectural detail
L28	Top part of a monk's tonsured head
L34 blue	Drapery detail of folds
L29	Border pattern, half dog rose with silver stained highlights
L30	Architectural detail with silver staining and stipple shading
L37	
L38	
L702	
L714	
L719	

APPENDIX 6

Spectrum	
R6	Partial stiff leaf terminal with pointed cusp on plain and cross-hatched ground
R7	Linked palmette design on a cross-hatched ground
R8	Two paired foliate motifs, one trefoil head and another lobed motif on a cross-hatched ground
R9	Two parallel partial side curling trefoil leaf terminals on a cross-hatched ground
R10	Trefoil leaf terminal with pointed spur and veined sten on a cross-hatched ground
R12	Trefoil leaf terminal alongside veined stem on a cross-hatched ground
R13	Vegetal, possibly pineapple or acorn on fine cross-hatched ground
R14	Double headed veined foliate with on a cross-hatched ground
R19	Stickworked cross diaper of circles and squares
R2 green	Cursive foliage, possibly part of a figural scheme
R58 murrey	Drapery, detail of hook folds
R62	Plain
R17	Two partial oak leaves with veins
R44 amber	Grisaille quatrefoil in reserve with pointed lobes and veining, strapwork edging
R4	Possible architectural detail with cross-hatching
R5	Open beading in border
R20	Linear stickwork of crosses with circular terminals and open circles at intercises, open circle, and thick parallel and diagonal lines
R36	Diaper fragment showing incomplete pointed quatrefoil and rounded banding in reserve
R46	Open beading with thick border line
R1 amber	Grisaille quatrefoil pattern in reserve, strapwork border
R53 blue	Diaper pattern of foliate and open circles stick work
R3	Linear stickwork of open circles interspersed with pairs of linked circles
R11	Possible seaweed background pattern with multi-lobate edges, on plain ground
R26	Partial fleur de Lys in reserve
R35	Architectural crockets in reserve
R45 green	Apex of quarry painted with a running, cursive pattern
R50 pot red	Diaper pattern of lobed, branching leaves
R51 blue	Diaper pattern of foliate and open circles stick work
R52 blue	Diaper pattern of foliate and open-circles-stickwork
R63 blue	Repeating spiral motifs in reserve, possible border pattern
R24	Naively painted Side facing head
R25	Lower half of heraldic bird, possibly an eagle, in reserve
R55 green	Part rounded quarry with branching and budding stems and spikey foliage, as R56
R56 green	Spikey foliage, as R55
R54 green	Plain
R15	Foliate quatrefoil motif with multi-lobed edges and double internal veining
R18	Fruiting stems outlines
R23	Partial face with thick outlined nose anad mouth, smear shading
R29	Partial black Gothic letter
R30	Black Gothic lettering
R31	Black Gothic lettering
R21	Clenched hand with fingernail detail
R22	Foot with individual painted toe nails and edge of garment
R27	Black Gothic lettering 'T'?
R28	Partial black Gothic letter
R38	Stipple shaded architectural crockets
R39	Architectural crockets
R41	Stipple sghaded masonry detail
R43	Stipple shaded architectural detail, possible window
R32	Cabbage leaf crocket?
R33	Architectural ribbed vaulting with central boss, silver stained
R37	Architectural tracery detail with silver stained detail
R60	Plain
R61	Plain
R40	Stipple shaded architectural detail
R42	Stipple shaded architectural detail with silver stained highlights
R48 flashed red	Stickworked repeating foliate border pattern
R34	Foliate background, stipple shading and silver stained highlights

APPENDIX 7

Spectrum	
W1	Long curlng stem and partial lobe on cross-hatched ground
W4	Trefoil leaf terminal with pointed spur and curling stem on thickly painted cross-hatched ground
W5	Open beading border
W9	Trefoil leaf terminal on cross-hatched ground
W27 blue plain	
W31 plain	
W2	Concentric bands of strapwork with cross hatching
W3	Upright trefoil wlth a central vein and smear shading , on cross-hatched ground
W6	Open beading border
W10	Three berries
W8	Apex of quarry showing naturalistic foliate motif with strapwork
W11	Linear stickwork of crosses with circular terminals, open circle and thin parallel edging line
W15	Stickworked circles and thick line
W25 streaky red pl	
W26 streaky red pl	
W7	Indistinct possible foliate design
W17	Possible border/strapwork design highlighted in silver stain, as W18, W19
W18	Possible border/strapwork design highlighted in silver stain, as W17, W19
W19	Possible border/strapwork design highlighted in silver stain, as W17, W18
W28 blue pl	
W16	Painted multi-petalled flower, possibly dog rose, stipple shaded
W13	Architectural detail of tower, windows with saltire cross, silver stained
W14	Architectural detail with silver staining and stipple shading
W20	Indistinct decoration
W21 red pl	
W24 streaky red pl	
W22	Stipple shaded architectural detail
W30	
W33	

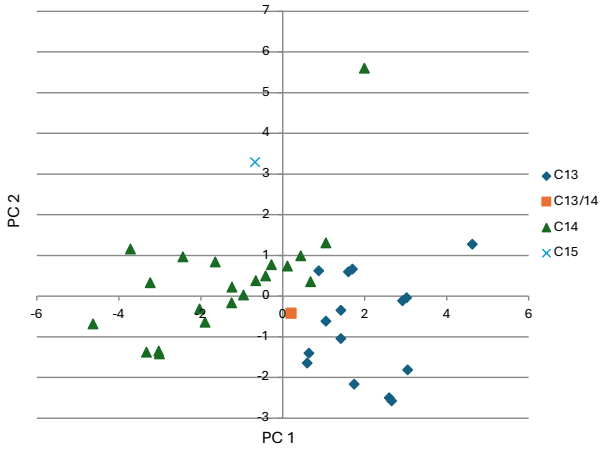
APPENDIX 9

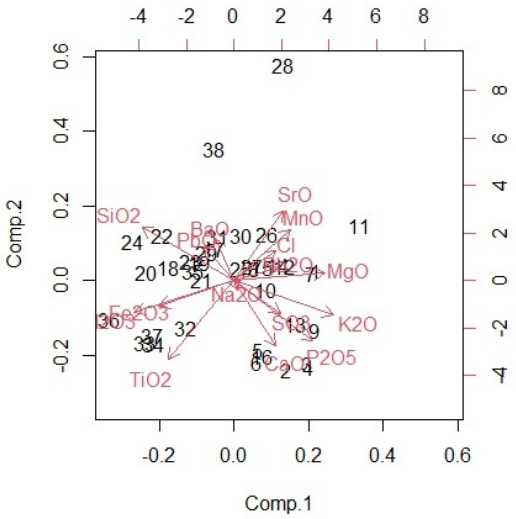
Compositional dating

Changes in glass compositions and glassmaking techniques may also help date a glass, some examples are shown in the following table. The date ranges are broad but nonetheless may provide a TPQ or TAQ that can help in the initial stages of dating window glass.

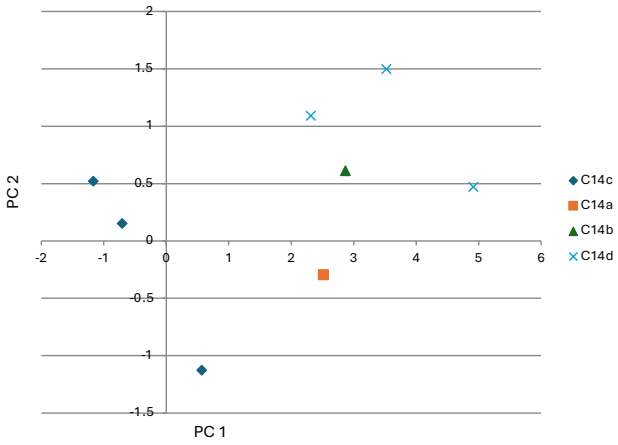
Composition/ glassmaking techniques	Dates	Reference
The chronology of red glass, from opaque to striated (and streaky) to flashed red can be used for the TPQ or TAQ	Opaque red (and other colours) TAQ around C13 Striated or streaky, C12-14 Flashed red and other colours, TPQ late C14/15	Kunicki et al.,2014, see section 2.4
HLLA composition	Used from the late C14/early C15	Wedepohl, 2010, see section 2.3.5
Glass thickness generally became thinner as glassmaking techniques improved	C15 glass is generally thinner than 13th century glass	As shown in this study, see technical results for all sites, e.g. 7.2.3
Fashion for different colours e.g. murrey	Murrey ceased to be used for skin tone by the early C15, less use of amber after development of silver stain	Westlake, 1882, p. 2 This study
Silver stain	Earliest use is 1307-12	Marks, 1993, p. 154

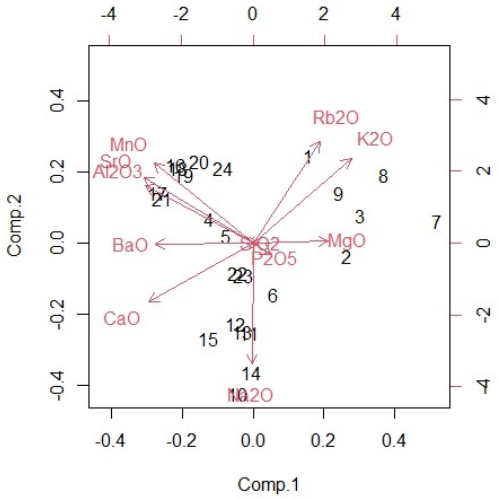
APPENDIX 10
ALCESTER PCA RESULTS



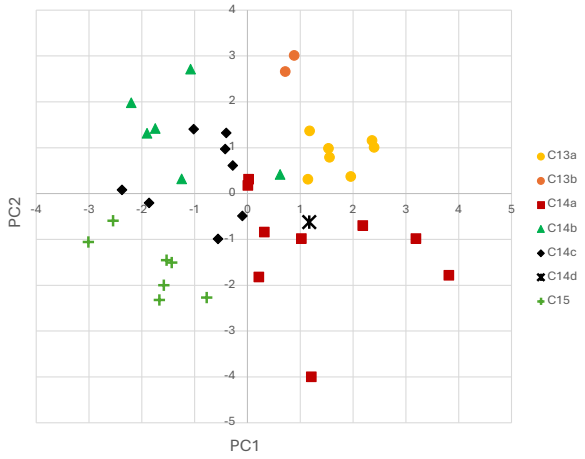


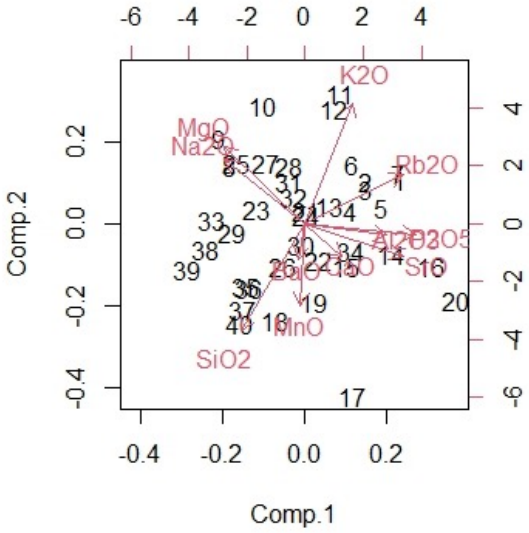
APPENDIX 11
BARDNEY PCA RESULTS



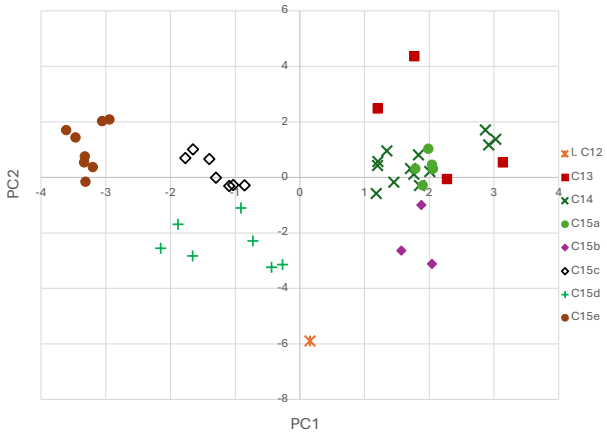


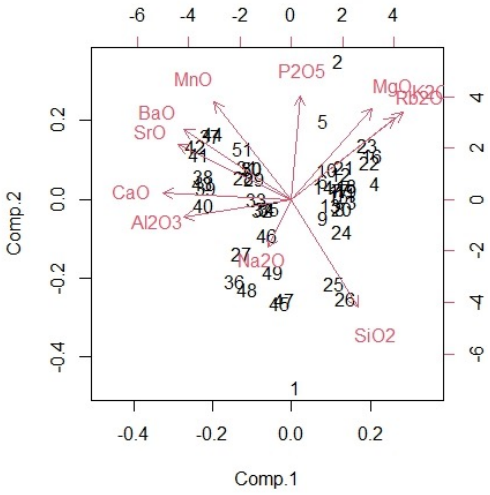
APPENDIX 12
BORDESLEY PCA RESULTS



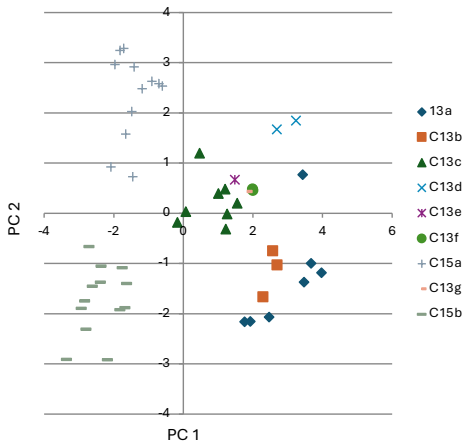


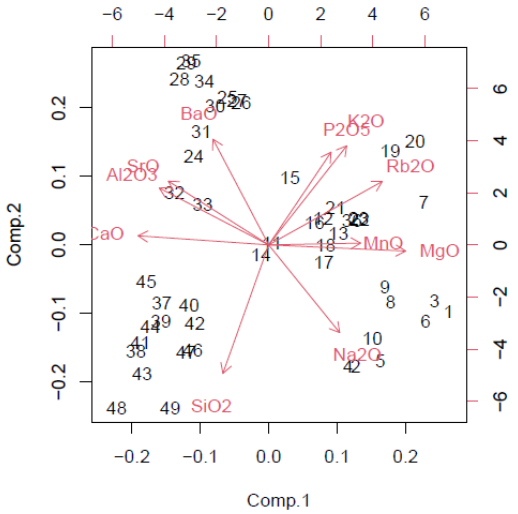
APPENDIX 13
HYDE PCA RESULTS



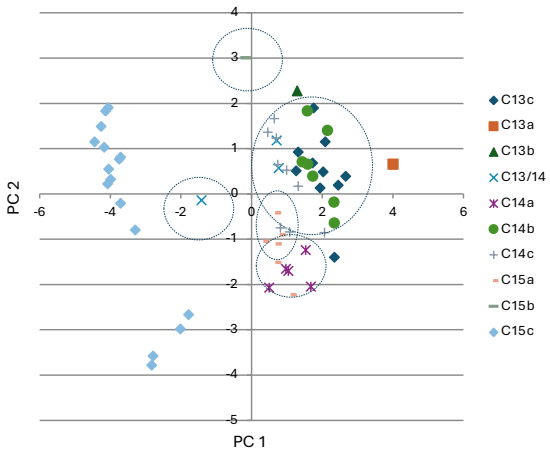


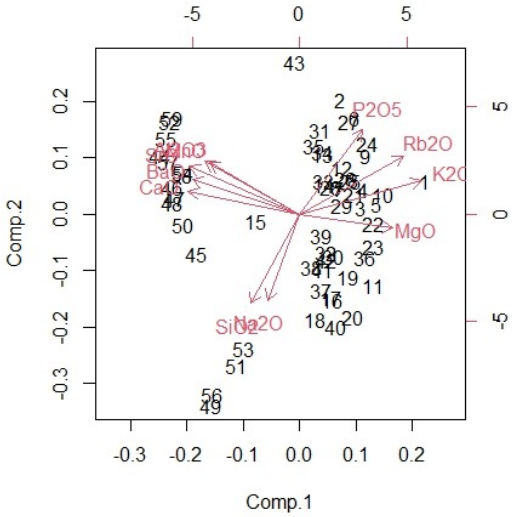
APPENDIX 14
LOUTH PARK PCA RESULTS



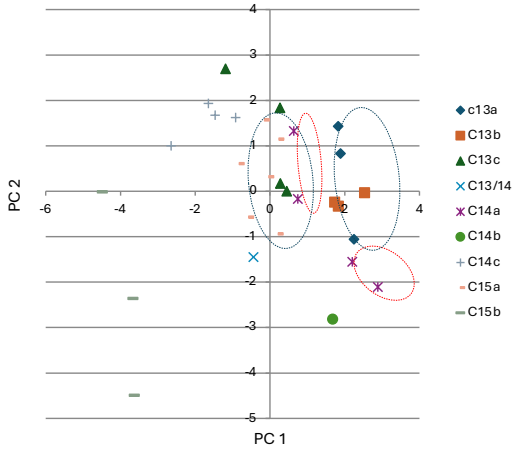


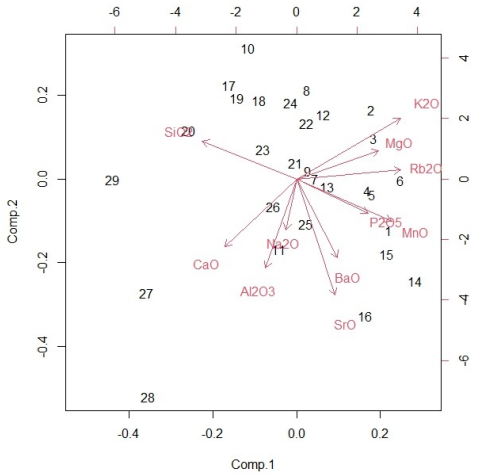
APPENDIX 15
RIEVAULX PCA RESULTS





APPENDIX 16
WHITBY PCA RESULTS





APPENDIX 17
PROPORTION OF VARIANCE

Alcester	Component 1	Component 2	**% CP (ave. 62%)**
Alcester 02			
Standard deviation	2.03	1.39	
Proportion of variance	0.38	0.17	
Cumulative proportion	0.38	0.55	**55**
Bardney 02			
Standard deviation	1.93	1.59	
Proportion of variance	0.34	0.23	
Cumulative proportion	0.34	0.57	**57**
Bordesley	Not recorded		
Standard deviation			
Proportion of variance			
Cumulative proportion			
Hyde			
Standard deviation	2.07	1.73	
Proportion of variance	0.39	0.67	
Cumulative proportion	**0.39**	**0.66**	**66**
Louth Park			
Standard deviation	2.16	1.75	
Proportion of variance	0.42	0.28	
Cumulative proportion	**0.42**	**0.71**	**71**
Rievaulx			
Standard deviation	2.33	1.45	
Proportion of variance	0.50	0.19	
Cumulative proportion	**0.50**	**0.69**	**69**
Whitby			
Standard deviation	1.90	1.61	
Proportion of variance	0.33	0.23	
Cumulative proportion	**0.33**	**0.56**	**56**

APPENDIX 18

Table listing each interference giving details of its effect and mitigation methods.

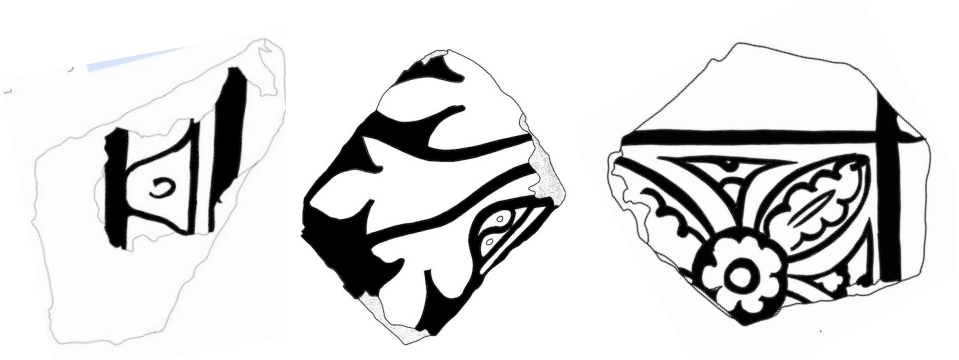
Measurement uncertainty	**Effects**	**How**	**Mitigation/correction methods**
Spectral interference	Overlapping spectral peaks	Secondary enhancement of the excited X-rays by other elements present	Avoid/minimise interference by limiting energy range of measured peak – or switch to another spectral line with no interference Use correction methods on data: fundamental parameters, influence coefficients, Compton rationing, multi-variate statistical analysis and dilution. Subtract calculated peak interference from measured peak – using reference material Machine needs twice yearly proficiency testing to identify 'laboratory bias' Always apply reference materials to prove lack of bias Filters can be used
	Peak on peak	K beta of one element overlaps the K alpha peak of another element, for instance	
	Compton scatter & Tailing	Can occur with less dense samples where the beam interacts with more material. Appears as a broad peak	
	Rayleigh scatter	X-rays are deflected by the sample back to the instrument resulting in a reading of the X-ray tube's anode	
	Escape peaks	The silicon material in the detector fluoresces with the X-rays from the sample resulting in loss of detected energy. The peak can be mis-interpreted for Cu in an alloy	
	Sum peaks, also known as double photon counting events	Mixing of two characteristic X-rays from elements of similar chemical composition resulting in a single peak	

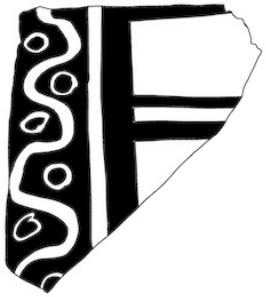
APPENDIX 19

Alcester Abbey

Parallel Hadzor church, Worcester, c.1340

APPENDIX 20a





Bardney Abbey

Parallel
Tewkesbury Abbey,
1338-40

APPENDIX 20b

Bardney

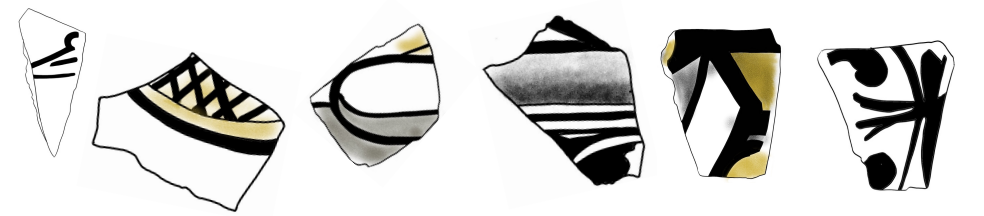
Parallel East
Harling, 1437-44

APPENDIX 21

Bordesley

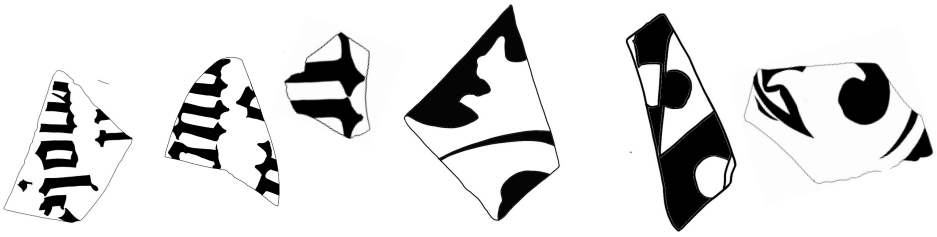
Parallel
Merton
College,
c. 1310

APPENDIX 22



Hyde

Parallel Wrangle, 1410-30



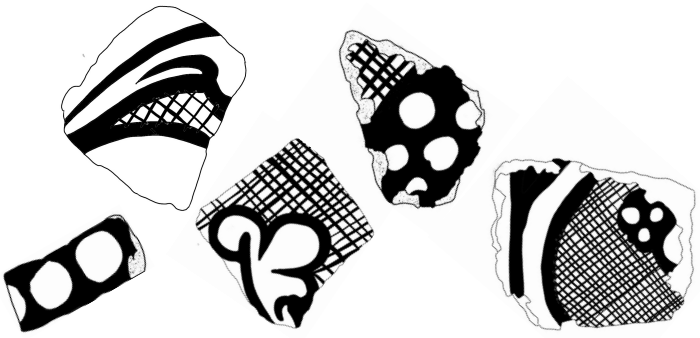
APPENDIX 23a

Louth Park

Parallel Stanton Harcourt, 1250-80

Louth Park

Parallel Salisbury Cathedral, early to mid C13



APPENDIX 23b

Louth Park

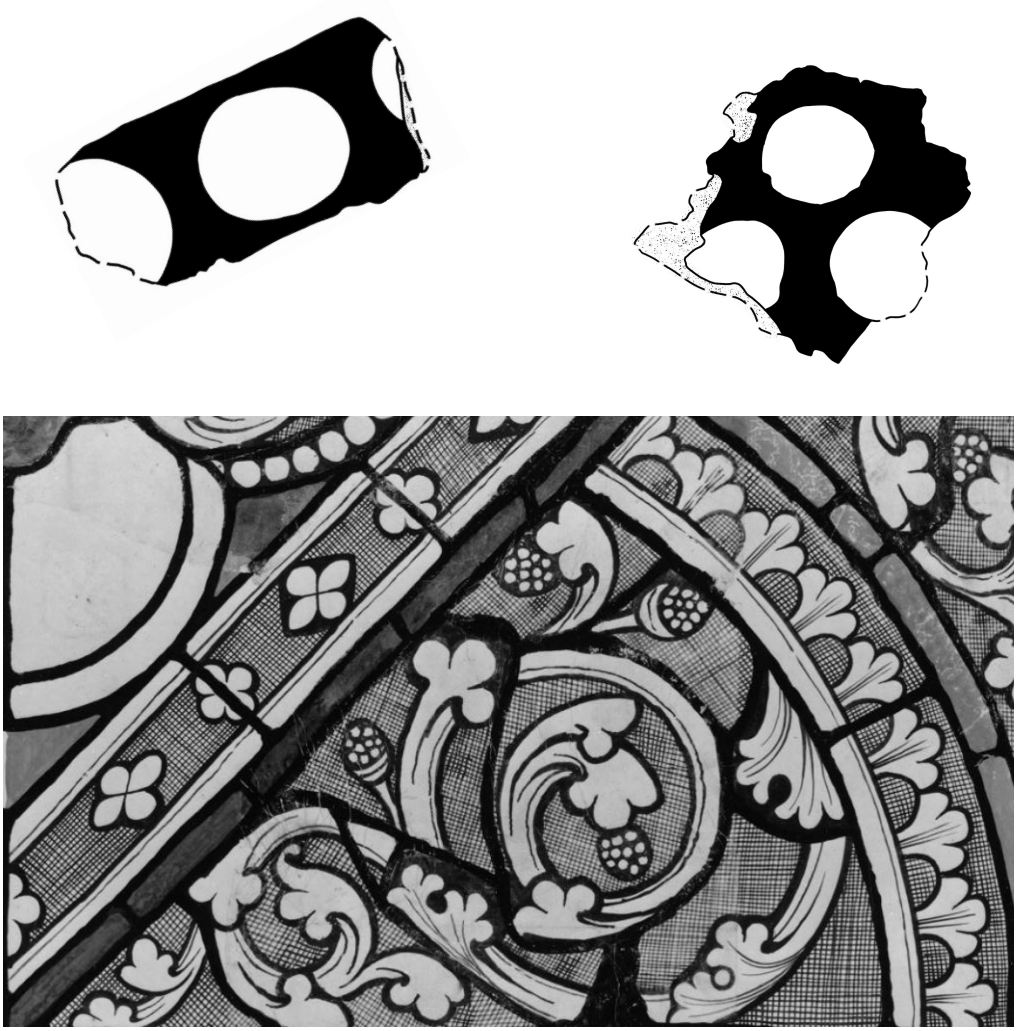
Parallel Great Malvern Priory, mid C15

APPENDIX 24

Rievaulx

Parallel East Harling, Norfolk,
The Ascension, late C15

APPENDIX 25



Whitby Abbey

Parallel Salisbury Cathedral early to mid C13

APPENDIX 26 Data set ALCESTER

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C13	Alc 5	0.27	18.04	0.85	5.85	14.94	0.09	0.03	0.14	0.11	0.01	0.86	1.48	0.00	0.03	0.05	1.29	50.40	5.38	0.10	0.07	0.00	0.00	0.83
	Alc 6	0.29	16.66	0.99	4.85	17.41	0.06	0.02	0.14	0.12	0.01	0.73	0.82	0.00	0.01	0.06	1.39	50.15	6.13	0.14	0.00	0.00	0.00	1.04
	Alc 12b	0.20	16.67	0.66	5.88	18.25	0.08	0.03	0.16	0.13	0.01	0.86	1.14	0.00	0.05	0.05	1.50	47.87	6.19	0.16	0.11	0.00	0.00	1.09
	Alc 14	0.20	16.82	0.86	5.95	18.43	0.08	0.03	0.17	0.13	0.01	0.87	1.15	0.00	0.05	0.06	1.60	47.14	6.19	0.13	0.11	0.00	0.00	1.10
	Alc 18	0.33	15.59	1.16	4.73	16.66	0.05	0.02	0.13	0.12	0.01	0.76	0.80	0.00	0.01	0.05	1.66	52.54	5.24	0.14	0.01	0.00	0.00	1.07
	Alc 20	0.31	15.52	1.47	4.92	16.61	0.04	0.02	0.13	0.12	0.01	0.74	0.79	0.00	0.01	0.05	1.68	52.15	5.29	0.14	0.00	0.00	0.00	1.07
	Alc 88	0.30	16.44	0.91	6.53	15.41	0.08	0.03	0.19	0.12	0.01	0.72	1.39	0.00	0.03	0.05	1.41	50.48	5.69	0.04	0.18	0.00	0.00	0.94
	Alc 65A streaky red, clear	0.35	17.25	1.14	7.70	13.14	0.09	0.03	0.13	0.10	0.01	0.65	1.65	0.00	0.03	0.06	0.89	50.58	6.03	0.11	0.05	0.00	0.00	0.76
	Alc 44 amber	0.41	16.76	0.74	4.61	15.08	0.08	0.05	0.13	0.10	0.01	0.89	0.83	0.00	0.03	0.04	1.57	53.89	4.59	0.17	0.03	0.00	0.00	0.90
	Alc 46 amber	0.32	16.23	0.92	5.24	16.41	0.08	0.02	0.19	0.12	0.01	0.81	1.18	0.00	0.04	0.06	1.78	50.86	4.83	0.73	0.17	0.00	0.00	1.01
	Alc 47 amber	0.38	16.50	1.05	5.33	14.78	0.08	0.04	0.12	0.10	0.01	0.85	0.79	0.00	0.03	0.03	1.63	53.66	4.57	0.02	0.02	0.00	0.00	0.90
	Alc 73C amber	0.38	15.74	0.92	5.60	14.46	0.07	0.02	0.12	0.12	0.01	0.79	1.34	0.00	0.05	0.06	2.08	53.87	4.19	0.13	0.05	0.00	0.00	0.92
	Alc 0742	0.12	15.11	0.44	4.61	18.12	0.10	0.03	0.28	0.13	0.01	0.78	1.35	0.01	0.05	0.05	1.75	51.93	4.76	0.00	0.39	0.00	0.00	1.20
	Alc 0748	0.22	16.80	0.70	6.14	17.81	0.09	0.03	0.15	0.13	0.01	0.86	1.30	0.01	0.09	0.06	1.19	48.29	5.93	0.06	0.14	0.00	0.00	1.06
	Alc 0897	0.18	15.17	0.44	4.91	16.45	0.09	0.03	0.16	0.13	0.01	0.92	1.35	0.01	0.10	0.07	1.36	52.56	5.71	0.00	0.35	0.00	0.00	1.08
C13/14	Alc 93	0.41	13.20	3.42	5.93	16.53	0.07	0.02	0.17	0.15	0.01	0.95	1.06	0.00	0.05	0.05	1.96	50.87	4.62	0.53	0.01	0.00	0.00	1.25
C14	Alc 74	0.34	13.10	1.32	5.23	15.91	0.08	0.02	0.16	0.12	0.01	0.98	1.14	0.01	0.21	0.06	2.34	54.16	3.96	0.01	0.77	0.00	0.09	1.21
	Alc 76M clear	0.27	12.17	0.64	3.13	15.68	0.08	0.02	0.18	0.13	0.01	1.10	1.19	0.00	0.18	0.06	2.84	56.50	4.95	0.00	0.81	0.00	0.06	1.29
	Alc 79 M clear	0.25	12.77	1.26	4.51	15.89	0.08	0.02	0.16	0.12	0.01	1.01	1.13	0.00	0.20	0.06	2.35	55.07	4.33	0.02	0.72	0.00	0.04	1.24
	Alc 86M	0.27	13.01	1.49	4.61	17.16	0.09	0.03	0.29	0.15	0.01	0.96	1.13	0.00	0.11	0.05	2.68	54.29	3.56	0.06	0.05	0.00	0.00	1.32
	Alc 90	0.32	12.01	0.58	3.71	14.35	0.08	0.02	0.15	0.12	0.01	1.02	1.08	0.00	0.19	0.06	3.15	58.54	3.74	0.11	0.70	0.00	0.07	1.20
	Alc 91M	0.29	12.48	1.22	4.75	15.18	0.07	0.02	0.24	0.13	0.01	0.90	0.93	0.00	0.10	0.04	2.19	57.60	3.70	0.06	0.07	0.00	0.00	1.22
	Alc 49 blue	0.31	13.19	1.50	5.66	15.29	0.08	0.02	0.15	0.12	0.01	1.29	1.14	0.07	0.32	0.10	1.95	54.08	3.90	0.00	0.79	0.00	0.06	1.16
	Alc 53 green	0.28	13.91	1.45	5.55	14.06	0.09	0.02	0.12	0.12	0.01	0.87	1.46	0.00	2.32	0.62	2.19	52.38	3.87	0.00	0.33	0.00	0.34	1.01
	Alc 57b green	0.28	12.84	1.36	5.23	14.77	0.08	0.02	0.15	0.11	0.01	1.02	1.10	0.01	2.72	0.29	1.78	53.37	3.92	0.00	0.71	0.00	0.23	1.15
	Alc 60 red striated	0.28	15.11	1.06	5.10	15.42	0.07	0.02	0.18	0.11	0.01	0.78	1.21	0.00	0.50	0.08	1.80	53.55	4.42	0.09	0.19	0.00	0.00	1.02
	Alc 61 striated clear	0.21	11.47	0.78	3.02	13.16	0.07	0.03	0.24	0.14	0.01	0.94	0.90	0.00	0.02	0.04	2.87	62.40	3.62	0.00	0.06	0.00	0.00	1.15
	Alc 68 amber	0.35	13.44	1.93	5.47	17.38	0.10	0.02	0.15	0.13	0.01	0.81	1.17	0.00	0.02	0.06	2.37	53.34	3.15	0.10	0.02	0.00	0.00	1.29
	Alc 75 murrey	0.31	13.47	0.59	5.06	15.68	0.06	0.03	0.14	0.10	0.01	0.62	1.63	0.00	0.02	0.04	1.83	56.16	4.08	0.18	0.00	0.00	0.00	1.16
	Alc 41	0.35	13.89	1.62	5.46	14.55	0.05	0.02	0.17	0.15	0.01	1.14	0.85	0.00	0.11	0.05	2.67	54.77	3.91	0.07	0.15	0.00	0.00	1.05
	Alc 41a SS	0.17	12.69	1.19	5.12	14.49	0.05	0.03	0.19	0.16	0.01	1.24	0.83	0.00	0.08	0.05	3.38	56.41	3.84	0.00	0.08	0.00	0.00	1.14
	Alc 42 SS	0.22	13.68	1.24	4.43	14.38	0.05	0.03	0.19	0.16	0.01	1.18	0.83	0.00	0.07	0.05	3.27	56.06	4.07	0.00	0.07	0.00	0.00	1.05
	Alc 42b SS	0.19	12.76	1.23	4.67	15.80	0.08	0.02	0.16	0.13	0.01	0.97	1.10	0.00	0.18	0.06	2.26	55.64	4.00	0.04	0.66	0.00	0.04	1.24
	Alc 80 SS	0.19	12.24	0.91	3.67	14.73	0.07	0.02	0.24	0.14	0.01	0.98	0.94	0.00	0.09	0.05	2.89	59.23	3.47	0.02	0.09	0.00	0.00	1.20
	Alc 92 SS	0.21	11.73	0.73	4.03	13.48	0.05	0.02	0.16	0.16	0.01	1.22	0.83	0.00	0.07	0.05	3.47	60.23	3.48	0.00	0.07	0.00	0.00	1.15
	Alc 0898	0.19	12.86	0.45	2.84	14.09	0.05	0.02	0.11	0.15	0.01	0.95	0.84	0.00	0.01	0.05	2.43	59.83	5.03	0.00	0.09	0.00	0.00	1.10
C16	Alc 43	0.23	9.56	0.50	4.47	15.50	0.06	0.01	0.13	0.08	0.00	0.46	1.57	0.00	0.01	0.06	0.74	63.91	2.63	0.03	0.05	0.00	0.00	1.62

APPENDIX 27 Data set BARDNEY

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C12	Bard 18 murrey	0.00	18.25	1.35	4.02	22.69	0.09	0.04	0.37	0.13	0.01	0.43	1.60	0.000	0.01	0.05	1.86	46.77	1.85	0.20	0.05	0.22	0.00	1.2
C14a	Bard 6	0.37	12.81	2.61	6.65	13.63	0.10	0.03	0.28	0.15	0.01	0.91	1.16	0.001	0.16	0.04	2.31	53.77	4.58	0.05	0.16	0.22	0.00	1.1
	Bard 11 M	0.15	9.18	1.50	7.17	17.70	0.07	0.01	0.17	0.14	0.01	0.67	1.61	0.006	0.02	0.07	1.45	56.93	2.70	0.17	0.03	0.21	0.00	1.9
14b	Bard 4	0.04	10.45	0.86	4.89	26.19	0.16	0.01	0.43	0.22	0.02	0.91	1.66	0.002	0.02	0.04	2.60	44.55	6.70	0.03	0.00	0.21	0.00	2.5
	Bard 13	0.03	11.16	0.91	5.40	26.13	0.16	0.01	0.49	0.20	0.02	0.89	1.37	0.003	0.02	0.04	2.17	42.17	8.55	0.06	0.00	0.21	0.00	2.3
	Bard 23 blue	0.13	9.74	1.98	5.36	25.66	0.09	0.01	0.33	0.15	0.01	1.73	1.58	0.172	0.16	0.11	1.57	43.69	7.15	0.12	0.03	0.21	0.00	2.6
C14c	Bard 5	0.34	16.14	1.59	6.39	14.14	0.10	0.03	0.18	0.14	0.01	0.84	1.32	0.004	0.18	0.08	1.82	51.80	4.55	0.06	0.08	0.22	0.00	0.9
	Bard 2 striated	0.29	17.09	0.84	3.58	16.93	0.04	0.03	0.02	0.11	0.01	0.65	0.48	0.001	0.01	0.04	0.86	52.95	5.73	0.13	0.00	0.22	0.00	1.0
	Bard 22	0.26	15.30	1.05	4.34	16.25	0.07	0.02	0.22	0.14	0.01	0.84	1.20	0.002	0.13	0.06	2.59	52.63	4.48	0.01	0.18	0.22	0.00	1.1
C15a	Bard 14 green	0.53	3.74	3.60	3.87	25.48	0.09	0.00	0.32	0.17	0.01	2.88	1.18	0.011	0.01	0.04	1.74	52.08	4.05	0.00	0.00	0.21	0.00	6.8
	Bard 7 blue	0.34	5.18	2.53	4.01	25.94	0.08	0.01	0.29	0.23	0.02	1.08	1.14	0.180	0.10	0.04	2.32	52.43	3.82	0.00	0.00	0.21	0.00	5.0
	Bard 8 blue	0.34	5.13	2.33	3.75	26.95	0.10	0.01	0.29	0.22	0.02	1.12	1.17	0.189	0.10	0.04	2.28	51.93	3.75	0.00	0.00	0.21	0.00	5.3
	Bard 25 green	0.52	3.41	3.47	3.54	25.25	0.09	0.01	0.28	0.17	0.01	4.49	1.13	0.018	0.01	0.04	1.68	51.58	4.08	0.00	0.00	0.21	0.00	7.4
	Bard 24 blue	0.34	5.16	2.64	3.82	25.79	0.09	0.01	0.30	0.22	0.02	1.08	1.13	0.178	0.10	0.04	2.39	52.63	3.82	0.00	0.00	0.21	0.00	5.0
	Bard 21	0.39	3.65	3.11	4.89	22.48	0.12	0.00	0.42	0.23	0.02	0.96	1.17	0.002	0.00	0.03	3.10	56.11	2.79	0.32	0.00	0.21	0.00	6.2
C15b	Bard 1	0.31	7.64	1.47	3.69	22.84	0.21	0.02	0.30	0.13	0.02	0.64	2.28	0.000	0.01	0.03	3.38	53.14	3.68	0.00	0.00	0.21	0.00	3.0
	Bard 9	0.18	6.70	1.30	3.47	24.14	0.17	0.01	0.32	0.14	0.01	0.58	2.33	0.000	0.01	0.03	3.85	52.97	3.58	0.00	0.00	0.21	0.00	3.6
	Bard 15	0.23	8.02	1.13	3.33	23.68	0.17	0.02	0.34	0.12	0.01	0.61	2.33	0.001	0.01	0.03	3.40	52.49	3.86	0.00	0.00	0.21	0.00	3.0
	Bard 16	0.23	7.97	1.30	3.51	23.31	0.17	0.02	0.34	0.12	0.01	0.59	2.27	0.000	0.01	0.03	3.33	52.70	3.89	0.00	0.00	0.21	0.00	2.9
	Bard 20	0.23	8.10	0.87	3.87	21.68	0.16	0.02	0.31	0.15	0.01	0.81	1.89	0.001	0.01	0.03	4.07	53.69	3.86	0.02	0.00	0.21	0.00	2.7
	Bard 3 flashed red	0.25	8.76	2.31	4.31	23.28	0.11	0.01	0.35	0.27	0.03	0.91	1.74	0.002	0.06	0.06	2.36	50.78	4.12	0.09	0.00	0.22	0.00	2.7
	Bard 10 blue	0.17	6.74	1.34	3.45	24.30	0.15	0.01	0.32	0.14	0.01	0.61	2.37	0.001	0.01	0.03	3.94	52.63	3.58	0.00	0.00	0.21	0.00	3.6
	Bard 19	0.00	7.98	0.84	4.16	22.24	0.12	0.03	0.46	0.20	0.02	0.92	2.14	0.015	0.01	0.02	2.42	55.70	2.29	0.17	0.05	0.21	0.00	2.8

APPENDIX 28 Data set BORDESLEY

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C13a	B1	0.28	14.80	0.93	5.96	17.46	0.11	0.04	0.14	0.14	0.01	0.90	1.36	0.00	0.11	0.07	1.74	49.51	6.29	0.10	0.03	0.00	0.00	1.2
	B2	0.33	15.09	1.09	5.43	14.61	0.09	0.04	0.14	0.17	0.01	0.88	1.29	0.00	0.03	0.07	2.10	53.31	5.26	0.00	0.05	0.00	0.00	1.0
	B5	0.28	14.79	1.39	5.92	17.97	0.11	0.03	0.16	0.16	0.01	1.02	1.46	0.02	0.11	0.09	1.86	49.01	5.27	0.08	0.27	0.00	0.00	1.2
	B7	0.27	14.46	1.25	4.94	16.75	0.10	0.03	0.14	0.16	0.01	1.01	1.39	0.02	0.12	0.08	1.97	52.47	4.52	0.06	0.26	0.00	0.00	1.2
	B8	0.38	14.28	0.93	5.39	17.64	0.10	0.03	0.16	0.15	0.01	0.88	1.36	0.00	0.11	0.07	2.06	50.20	6.15	0.07	0.03	0.00	0.00	1.2
	B17	0.26	14.89	1.31	6.42	18.01	0.09	0.03	0.13	0.13	0.01	0.87	1.29	0.00	0.06	0.07	1.54	48.66	6.04	0.10	0.09	0.00	0.00	1.2
	B18	0.30	14.86	0.98	6.22	17.24	0.11	0.04	0.13	0.14	0.01	0.88	1.38	0.00	0.13	0.08	1.71	49.20	6.45	0.12	0.03	0.00	0.00	1.2
C13b	B46M green	0.25	17.87	1.78	5.77	15.24	0.06	0.04	0.32	0.13	0.01	0.73	1.03	0.00	2.12	0.13	1.77	47.98	4.51	0.07	0.15	0.00	0.04	0.9
	B36 blue	0.21	18.96	1.63	6.00	15.01	0.06	0.02	0.14	0.15	0.01	1.51	1.15	0.11	0.24	0.51	2.12	45.32	6.32	0.00	0.50	0.00	0.03	0.8
C14a	B12	0.29	14.94	1.00	2.85	16.67	0.10	0.04	0.18	0.19	0.01	1.19	1.82	0.01	0.04	0.13	2.26	53.81	4.18	0.01	0.30	0.00	0.00	1.1
	B16	0.40	10.85	1.35	3.09	16.42	0.07	0.03	0.25	0.16	0.01	1.16	0.85	0.00	0.14	0.06	2.71	56.96	5.32	0.00	0.17	0.00	0.00	1.5
	B20	0.49	13.87	0.83	3.74	13.97	0.14	0.04	0.17	0.16	0.01	0.91	1.76	0.00	0.02	0.07	2.48	54.84	6.27	0.00	0.24	0.00	0.00	1.0
	B24	0.30	8.18	0.84	2.31	15.43	0.10	0.02	0.28	0.14	0.01	0.74	1.88	0.00	0.01	0.06	1.94	59.44	8.12	0.00	0.21	0.00	0.00	1.9
	B29	0.36	11.11	1.46	4.85	16.26	0.10	0.02	0.27	0.12	0.01	0.67	1.84	0.00	0.01	0.06	1.58	54.87	6.24	0.00	0.17	0.00	0.00	1.5
	B33	0.25	10.39	0.83	2.49	17.22	0.10	0.03	0.16	0.14	0.01	0.79	1.49	0.00	0.02	0.05	2.52	52.48	11.02	0.00	0.02	0.00	0.00	1.7
	B37 amber	0.38	13.25	1.43	4.33	16.11	0.06	0.02	0.12	0.14	0.01	1.04	0.85	0.00	0.02	0.03	2.65	55.41	4.14	0.00	0.01	0.00	0.00	1.2
	B38 amber	0.39	13.24	1.19	4.25	16.01	0.06	0.02	0.11	0.14	0.01	1.04	0.84	0.00	0.02	0.03	2.50	55.99	4.16	0.00	0.01	0.00	0.00	1.2
	B44 amber	0.29	13.82	1.20	3.45	14.02	0.07	0.02	0.18	0.11	0.01	0.58	1.47	0.00	0.01	0.06	2.25	56.81	5.55	0.10	0.00	0.00	0.00	1.0
	B19	0.26	16.34	0.84	2.15	19.36	0.10	0.02	0.12	0.16	0.01	0.79	1.54	0.00	0.02	0.07	1.37	52.85	3.79	0.19	0.02	0.00	0.00	1.2
C14b	B10	0.43	14.53	1.37	6.37	14.28	0.12	0.03	0.14	0.17	0.01	0.93	1.51	0.00	0.05	0.06	2.01	54.15	3.71	0.09	0.04	0.00	0.00	1.0
	B27	0.42	17.93	1.32	7.87	11.98	0.07	0.03	0.17	0.06	0.00	0.33	1.02	0.00	0.02	0.06	0.84	53.45	4.39	0.04	0.00	0.00	0.00	0.7
	B28 blue	0.40	13.82	1.60	5.60	13.65	0.08	0.03	0.22	0.08	0.00	0.70	1.23	0.08	0.19	0.34	1.08	57.38	3.17	0.05	0.31	0.00	0.00	1.0
	B41	0.36	15.34	2.57	7.14	12.07	0.07	0.03	0.18	0.09	0.00	0.55	1.83	0.00	0.01	0.06	1.15	54.86	3.60	0.10	0.00	0.00	0.00	0.8
	B42 bulls eye	0.47	13.18	2.12	5.93	14.04	0.04	0.02	0.07	0.24	0.02	0.81	0.80	0.01	0.03	0.04	2.11	56.27	3.66	0.09	0.08	0.00	0.00	1.1
	B43	0.34	15.48	2.93	8.03	12.40	0.06	0.03	0.18	0.09	0.00	0.54	1.83	0.00	0.01	0.05	1.15	52.93	3.84	0.11	0.00	0.00	0.00	0.8
	B11	0.29	10.87	1.96	6.51	16.37	0.11	0.02	0.26	0.12	0.01	0.65	1.57	0.00	0.01	0.06	1.67	54.81	4.68	0.01	0.04	0.00	0.00	1.5
	B14	0.41	12.33	3.10	5.95	18.60	0.07	0.02	0.12	0.12	0.01	0.58	0.96	0.00	0.02	0.04	1.66	51.14	4.80	0.06	0.00	0.00	0.00	1.5
	B15	0.39	13.11	3.00	6.81	18.09	0.09	0.02	0.23	0.14	0.02	0.78	1.17	0.00	0.01	0.06	1.78	48.81	5.42	0.06	0.01	0.00	0.00	1.4
	B30	0.45	10.52	2.62	8.35	18.21	0.09	0.01	0.27	0.11	0.01	0.53	1.58	0.00	0.01	0.04	1.56	51.13	4.47	0.05	0.00	0.00	0.00	1.7
	B47M	0.38	12.33	2.07	6.05	17.21	0.12	0.02	0.27	0.12	0.01	0.60	1.44	0.00	0.01	0.04	1.58	53.04	4.61	0.07	0.01	0.00	0.00	1.4
	B23 amber	0.35	12.96	2.63	6.37	14.84	0.08	0.02	0.28	0.16	0.01	0.86	1.20	0.00	1.59	0.21	2.10	50.21	5.72	0.01	0.30	0.00	0.10	1.1
	B35 blue	0.27	12.98	1.86	6.59	15.14	0.09	0.03	0.18	0.12	0.01	1.07	1.46	0.09	0.22	0.32	1.42	52.80	4.85	0.00	0.47	0.00	0.02	1.2
	B40 red, striated	0.36	10.75	3.12	5.01	16.99	0.05	0.01	0.14	0.14	0.01	0.87	1.12	0.00	0.86	0.11	2.27	55.21	2.87	0.05	0.04	0.00	0.00	1.6
C15	B21	0.27	11.21	1.35	4.77	14.73	0.07	0.02	0.17	0.12	0.01	0.66	1.53	0.00	0.01	0.06	1.61	60.05	3.20	0.11	0.04	0.00	0.00	1.3
	B26	0.23	9.88	0.85	5.75	17.19	0.09	0.02	0.20	0.09	0.01	0.56	1.93	0.00	0.01	0.08	1.12	57.11	4.69	0.00	0.19	0.00	0.00	1.7
	B31	0.26	11.61	1.25	4.56	15.05	0.07	0.02	0.20	0.12	0.01	0.64	1.50	0.00	0.01	0.06	1.60	59.86	3.02	0.13	0.04	0.00	0.00	1.3
	B32	0.21	9.84	1.22	5.33	15.98	0.07	0.02	0.18	0.09	0.00	0.53	1.66	0.00	0.01	0.06	1.80	60.10	2.81	0.03	0.05	0.00	0.00	1.6
	B45M	0.24	10.00	1.34	8.20	16.64	0.06	0.02	0.13	0.08	0.00	0.44	1.64	0.00	0.01	0.06	1.00	56.78	3.22	0.14	0.01	0.00	0.00	1.7
	B48M	0.26	10.04	1.25	8.10	16.67	0.06	0.01	0.15	0.08	0.01	0.49	1.72	0.00	0.01	0.09	0.95	56.75	3.19	0.17	0.02	0.00	0.00	1.7
	B39 SS	0.24	9.79	1.19	4.63	16.58	0.07	0.02	0.19	0.09	0.00	0.53	1.69	0.00	0.01	0.07	1.49	60.59	2.69	0.07	0.05	0.00	0.00	1.7

APPENDIX 29 Data set HYDE

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	CaK
C12	H41 blue	0.60	3.99	7.16	1.30	9.86	0.07	0.00	0.04	0.18	0.01	1.59	0.79	0.07	0.25	0.01	3.27	68.02	2.63	0.00	0.32	0.34	0.00	2.7
C13	H18	0.38	13.51	1.42	7.29	13.46	0.12	0.04	0.33	0.16	0.02	0.83	2.04	0.01	0.03	0.07	1.19	53.94	5.03	0.09	0.03	0.00	0.00	1.0
	H15	0.37	11.60	1.34	6.65	13.63	0.09	0.03	0.13	0.14	0.01	0.79	1.19	0.01	0.01	0.06	1.14	59.29	5.56	0.12	0.03	0.00	0.00	1.2
	H17	0.33	11.63	1.51	5.65	13.10	0.07	0.03	0.09	0.12	0.01	1.06	1.06	0.01	0.07	0.05	1.22	59.57	4.66	0.06	0.08	0.00	0.00	1.1
	H19	0.22	11.67	0.55	3.92	13.05	0.11	0.04	0.36	0.20	0.01	0.83	2.00	0.00	0.03	0.07	1.65	60.58	4.44	0.06	0.01	0.00	0.00	1.1
C14	H31	0.20	9.51	1.96	5.91	15.73	0.10	0.02	0.17	0.21	0.02	1.15	1.34	0.01	0.03	0.06	1.94	57.88	3.96	0.00	0.21	0.00	0.00	1.7
	H32	0.28	12.93	0.80	5.12	13.14	0.07	0.03	0.13	0.08	0.01	0.73	1.28	0.01	0.02	0.06	1.24	58.91	5.03	0.06	0.08	0.00	0.00	1.0
	H52	0.39	10.46	0.66	4.91	15.57	0.11	0.03	0.17	0.12	0.01	0.69	1.34	0.01	0.01	0.05	1.63	60.68	3.05	0.07	0.03	0.00	0.00	1.5
	H14 SS	0.32	13.37	1.14	4.87	12.20	0.08	0.03	0.13	0.16	0.01	0.91	1.14	0.00	0.01	0.05	1.67	58.81	4.96	0.06	0.08	0.00	0.00	0.9
	H56 SS	0.37	10.46	1.15	5.48	14.04	0.09	0.02	0.14	0.20	0.02	1.11	1.17	0.01	0.02	0.05	1.98	60.29	3.18	0.10	0.14	0.00	0.00	1.3
	H65 SS	0.34	11.83	1.10	5.04	14.40	0.10	0.02	0.18	0.22	0.02	1.15	1.35	0.01	0.03	0.06	2.16	61.03	3.29	0.00	0.09	0.00	0.00	1.4
	H86 SS	0.23	11.33	0.76	5.23	15.82	0.10	0.02	0.18	0.16	0.01	1.03	1.41	0.01	0.01	0.05	1.74	57.68	4.09	0.00	0.14	0.00	0.00	1.4
	H87 SS	0.23	14.04	1.22	5.58	12.91	0.08	0.03	0.15	0.17	0.01	0.98	1.19	0.00	0.01	0.06	1.61	56.74	4.90	0.02	0.09	0.00	0.00	0.9
	H197	0.21	11.04	0.98	4.43	14.64	0.08	0.02	0.12	0.13	0.01	0.79	1.32	0.00	0.02	0.06	1.39	59.98	4.35	0.01	0.39	0.00	0.02	1.3
	H251	0.27	11.79	1.46	6.17	15.42	0.09	0.02	0.16	0.15	0.01	0.86	1.31	0.01	0.01	0.05	1.52	56.85	3.68	0.00	0.18	0.00	0.00	1.3
	H263	0.13	11.06	1.51	5.19	14.94	0.09	0.02	0.14	0.23	0.02	1.25	1.27	0.01	0.02	0.06	2.41	58.48	3.03	0.00	0.15	0.00	0.00	1.4
	H266	0.27	9.25	1.34	5.42	17.24	0.11	0.02	0.15	0.13	0.01	0.78	1.22	0.01	0.01	0.06	1.44	58.30	4.11	0.00	0.14	0.00	0.00	1.9
	H269	0.21	10.00	0.42	3.95	14.70	0.08	0.02	0.13	0.14	0.01	0.78	1.27	0.01	0.01	0.05	1.64	61.64	3.08	0.00	0.24	0.00	0.00	1.5
C15a	H53	0.40	10.53	2.04	6.39	16.49	0.09	0.02	0.14	0.11	0.02	0.63	1.18	0.01	0.01	0.05	1.28	57.09	3.48	0.13	0.11	0.00	0.00	1.5
	H55	0.28	11.69	1.41	5.61	13.67	0.09	0.02	0.11	0.21	0.02	1.35	1.24	0.01	0.03	0.06	1.97	58.15	4.02	0.00	0.08	0.00	0.00	1.2
	H57	0.18	11.62	1.81	5.86	12.59	0.09	0.02	0.10	0.24	0.02	1.35	1.31	0.01	0.08	0.08	2.24	58.28	3.79	0.00	0.29	0.00	0.02	1.1
	H82	0.27	10.73	1.93	5.68	14.03	0.08	0.02	0.14	0.20	0.02	1.10	1.18	0.01	0.02	0.05	2.00	59.16	3.15	0.09	0.14	0.00	0.01	1.3
	H89	0.27	11.82	2.09	6.18	15.23	0.08	0.02	0.15	0.14	0.01	0.81	1.18	0.01	0.01	0.05	1.57	55.67	4.54	0.01	0.15	0.00	0.00	1.3
C15b	H54	0.15	8.79	0.37	3.06	12.68	0.09	0.02	0.14	0.12	0.01	0.63	1.25	0.01	0.01	0.05	1.46	66.83	4.24	0.00	0.10	0.00	0.00	1.4
	H59	0.15	7.65	0.37	1.85	12.58	0.08	0.02	0.14	0.15	0.01	0.80	1.12	0.01	0.01	0.05	2.14	69.92	2.86	0.00	0.11	0.00	0.00	1.6
	H170	0.14	7.86	0.37	1.45	13.30	0.08	0.02	0.10	0.15	0.01	0.69	0.84	0.00	0.02	0.03	2.18	69.49	3.15	0.03	0.23	0.00	0.00	1.7
C15c	H48 flashed red clear	0.34	7.23	3.12	4.10	23.80	0.08	0.01	0.38	0.30	0.02	0.73	1.67	0.00	0.03	0.06	1.85	52.10	4.02	0.16	0.00	0.00	0.00	3.3
	H8 flashed red clear	0.28	7.29	2.20	3.85	22.33	0.10	0.01	0.34	0.25	0.03	0.64	1.50	0.00	0.01	0.05	1.83	54.57	4.57	0.14	0.00	0.00	0.00	3.1
	H9 flashed red, red	0.24	5.90	2.25	4.24	23.99	0.15	0.01	0.21	0.13	0.02	0.69	1.32	0.00	0.20	0.04	1.92	52.99	5.64	0.01	0.05	0.00	0.00	4.1
	H43 blue	0.08	6.75	2.12	3.93	22.44	0.14	0.01	0.21	0.11	0.02	0.91	1.11	0.17	0.10	0.04	1.83	55.88	3.96	0.09	0.04	0.00	0.00	3.3
	H46 blue	0.10	6.83	2.31	4.22	23.01	0.15	0.01	0.22	0.12	0.02	0.92	1.13	0.18	0.11	0.04	1.78	54.69	3.99	0.11	0.04	0.00	0.00	3.4
	H47 blue	0.09	6.85	2.04	4.22	21.81	0.14	0.01	0.22	0.12	0.01	0.94	1.18	0.17	0.14	0.04	1.84	56.29	3.71	0.12	0.02	0.00	0.00	3.2
	H49 blue	0.13	7.14	1.88	4.29	21.54	0.13	0.01	0.22	0.12	0.02	0.96	1.17	0.17	0.13	0.03	1.90	56.24	3.67	0.19	0.02	0.00	0.00	3.0
C15d	H37	0.47	7.54	1.90	4.41	22.88	0.16	0.01	0.19	0.12	0.01	0.98	0.70	0.00	0.01	0.03	1.85	56.12	3.61	0.04	0.03	0.00	0.00	4.3
	H51	0.40	3.38	2.86	4.31	23.74	0.16	0.00	0.15	0.15	0.01	0.78	0.91	0.00	0.01	0.04	2.06	57.41	3.63	0.06	0.03	0.00	0.00	7.2
	H92	0.33	5.48	1.21	3.65	23.31	0.09	0.01	0.26	0.15	0.01	0.46	1.11	0.00	0.01	0.04	1.73	58.99	3.68	0.07	0.02	0.00	0.00	4.3
	H72	0.27	3.07	2.33	2.54	23.48	0.13	0.00	0.23	0.25	0.03	0.74	0.80	0.00	0.01	0.03	2.54	60.06	3.30	0.18	0.02	0.00	0.00	7.7
	H75 SS	0.24	4.80	0.78	2.03	20.43	0.07	0.01	0.22	0.16	0.01	0.42	1.03	0.00	0.03	0.04	1.98	65.56	2.11	0.09	0.00	0.00	0.00	4.3
	H79 SS	0.38	3.26	1.64	2.47	21.45	0.10	0.00	0.21	0.24	0.03	0.70	1.05	0.00	0.00	0.05	2.86	62.19	3.03	0.33	0.00	0.00	0.00	6.6
	H84 SS	0.05	5.86	0.61	2.46	20.81	0.10	0.01	0.18	0.42	0.04	0.80	1.20	0.00	0.01	0.03	2.64	62.43	2.33	0.01	0.00	0.00	0.00	3.5
C15e	H50	0.20	7.64	1.11	3.27	21.63	0.19	0.02	0.32	0.13	0.02	0.72	2.28	0.00	0.01	0.04	3.90	54.34	4.19	0.00	0.02	0.00	0.00	2.8
	H195 SS	0.31	7.10	1.09	3.03	21.67	0.15	0.01	0.28	0.11	0.01	0.68	2.13	0.00	0.01	0.03	4.41	56.45	4.47	0.00	0.02	0.00	0.00	3.1
	H73 SS	0.27	6.94	0.91	2.63	21.10	0.15	0.01	0.32	0.11	0.01	0.68	2.10	0.00	0.01	0.03	4.63	56.67	3.39	0.00	0.02	0.00	0.00	3.0
	H71 SS	0.22	6.10	0.42	1.58	19.89	0.15	0.01	0.30	0.11	0.01	0.89	2.06	0.00	0.00	0.03	5.25	59.42	3.75	0.00	0.02	0.00	0.00	3.3
	H74 SS	0.17	7.19	1.20	3.46	23.90	0.16	0.01	0.34	0.12	0.01	0.48	2.21	0.00	0.01	0.03	3.88	52.98	3.84	0.01	0.00	0.00	0.00	3.3
	H76 SS	0.16	7.16	1.49	3.63	23.15	0.17	0.01	0.34	0.11	0.01	0.69	2.24	0.00	0.01	0.04	4.12	52.47	4.17	0.04	0.00	0.00	0.00	3.2
	H61 SS	0.32	6.90	1.12	2.83	21.48	0.16	0.01	0.32	0.11	0.01	0.68	2.13	0.00	0.01	0.03	4.50	56.01	3.38	0.00	0.00	0.00	0.00	3.1
	H84a SS	0.38	7.48	1.02	3.64	21.99	0.18	0.02	0.32	0.13	0.02	0.71	2.28	0.00	0.01	0.04	3.86	53.79	4.15	0.00	0.00	0.00	0.00	2.9

APPENDIX 30 Data set LOUTH PARK

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C13a	L1	0.46	9.69	6.37	9.25	14.15	0.07	0.05	0.32	0.07	0.01	0.56	1.77	0.00	0.01	0.08	1.50	51.20	4.39	0.06	0.00	0.00	0.00	1.5
	L6	0.38	9.89	3.24	5.87	13.44	0.06	0.03	0.11	0.14	0.01	1.36	1.36	0.01	0.01	0.06	1.46	58.46	3.97	0.12	0.01	0.00	0.00	1.4
	L9	0.33	9.28	4.41	9.11	14.32	0.05	0.05	0.30	0.08	0.00	0.55	1.71	0.00	0.01	0.07	1.51	53.38	4.81	0.00	0.02	0.00	0.00	1.5
	L11	0.33	10.61	3.30	5.60	13.25	0.08	0.03	0.11	0.12	0.02	1.31	1.36	0.01	0.03	0.06	1.34	58.76	3.62	0.04	0.02	0.00	0.00	1.2
	L12	0.47	15.66	3.02	7.79	12.64	0.07	0.03	0.10	0.15	0.01	0.77	1.16	0.01	0.01	0.06	1.26	52.85	3.86	0.05	0.06	0.00	0.00	0.8
	L13	0.35	10.97	4.45	6.91	13.42	0.08	0.03	0.11	0.11	0.02	1.25	1.37	0.01	0.02	0.06	1.17	55.74	3.84	0.10	0.01	0.00	0.00	1.2
	L16	0.37	9.47	5.12	8.50	13.56	0.06	0.05	0.29	0.08	0.00	0.58	1.66	0.00	0.01	0.06	1.62	54.26	4.26	0.04	0.00	0.00	0.00	1.4
	L18	0.52	9.63	3.15	6.87	15.86	0.07	0.06	0.36	0.10	0.01	0.71	2.10	0.00	0.01	0.09	1.89	51.47	6.88	0.00	0.22	0.00	0.00	1.6
	L35	0.35	17.30	2.27	6.40	12.04	0.05	0.02	0.13	0.08	0.01	0.52	1.65	0.00	0.03	0.05	1.75	53.26	4.03	0.06	0.00	0.00	0.00	0.7
	L36	0.37	14.83	2.41	6.25	11.46	0.06	0.02	0.10	0.10	0.01	0.60	1.92	0.00	0.02	0.05	2.00	56.75	2.94	0.13	0.00	0.00	0.00	0.8
C13b	L2	0.25	12.55	1.24	6.77	17.46	0.09	0.02	0.30	0.15	0.01	1.15	0.83	0.01	0.01	0.08	2.62	52.49	3.79	0.17	0.00	0.00	0.00	1.4
	L5	0.23	12.97	1.03	5.31	16.85	0.07	0.03	0.24	0.12	0.01	0.80	1.33	0.00	0.08	0.06	2.15	52.68	5.76	0.20	0.08	0.00	0.00	1.3
	L7	0.33	14.82	1.00	5.68	14.97	0.07	0.03	0.14	0.14	0.01	0.91	1.36	0.00	0.03	0.07	2.23	52.90	5.10	0.11	0.10	0.00	0.00	1.0
	L8	0.14	12.09	1.33	6.36	17.16	0.09	0.02	0.31	0.15	0.01	1.16	0.82	0.01	0.01	0.07	2.80	53.82	3.57	0.06	0.01	0.00	0.00	1.4
	L10	0.18	14.06	1.38	5.26	16.77	0.07	0.03	0.25	0.16	0.01	1.14	1.37	0.01	0.08	0.07	4.23	49.72	5.03	0.03	0.15	0.00	0.00	1.2
	L14	0.22	15.78	0.69	4.92	15.41	0.06	0.03	0.09	0.12	0.01	1.53	0.92	0.01	0.01	0.07	2.47	52.30	5.33	0.00	0.03	0.00	0.00	1.0
	L19	0.40	14.58	1.29	6.69	17.17	0.06	0.02	0.08	0.09	0.01	1.30	1.00	0.01	0.01	0.07	1.94	50.88	4.31	0.08	0.00	0.00	0.00	1.2
	L26	0.35	10.03	1.66	6.28	15.68	0.09	0.03	0.19	0.09	0.01	0.68	1.81	0.00	0.01	0.07	2.51	53.41	6.98	0.00	0.13	0.00	0.00	1.6
	L43	0.38	14.88	1.15	6.19	16.34	0.08	0.03	0.07	0.09	0.01	1.26	1.00	0.01	0.01	0.07	2.00	51.76	4.58	0.09	0.00	0.00	0.00	1.1
	L44	0.33	17.44	0.96	6.06	15.83	0.06	0.03	0.09	0.11	0.01	1.45	0.92	0.01	0.01	0.07	2.29	49.26	4.99	0.09	0.00	0.00	0.00	0.9
C13c	L32 striated red	0.28	16.99	1.92	6.73	16.22	0.09	0.05	0.26	0.14	0.01	0.70	1.43	0.00	0.01	0.08	1.80	47.14	5.98	0.15	0.02	0.00	0.00	1.0
	L33 amber	0.31	18.38	1.59	7.29	13.87	0.10	0.05	0.16	0.11	0.01	0.59	1.47	0.00	0.01	0.05	1.76	47.45	6.70	0.09	0.00	0.00	0.00	0.8
	L3	0.38	13.24	2.22	6.76	16.12	0.06	0.03	0.35	0.10	0.01	0.71	1.33	0.01	0.07	0.06	1.77	50.85	5.73	0.08	0.14	0.00	0.00	1.2
	L4	0.39	13.25	1.91	6.87	16.07	0.06	0.03	0.34	0.10	0.01	0.72	1.34	0.01	0.07	0.06	1.76	51.07	5.71	0.10	0.14	0.00	0.00	1.2
C14/15	L15	0.05	12.04	0.69	3.14	21.12	0.14	0.03	0.54	0.14	0.01	0.67	0.97	0.00	0.02	0.02	3.30	52.59	4.45	0.00	0.07	0.00	0.00	1.8
	L20	0.01	14.13	0.69	4.30	21.17	0.17	0.02	0.64	0.14	0.01	0.66	1.48	0.00	0.02	0.04	2.82	48.27	5.25	0.16	0.00	0.00	0.00	1.5
	L21	0.02	14.36	0.69	4.56	20.84	0.15	0.02	0.63	0.15	0.01	0.66	1.46	0.00	0.02	0.04	2.75	48.13	5.38	0.13	0.00	0.00	0.00	1.5
	L22	0.02	14.22	0.70	4.68	21.06	0.16	0.02	0.63	0.16	0.01	0.65	1.46	0.00	0.02	0.04	2.77	47.97	5.30	0.13	0.01	0.00	0.00	1.5
	L40	0.00	14.13	0.69	3.74	23.89	0.19	0.03	0.87	0.16	0.02	0.74	1.40	0.00	0.01	0.03	3.10	47.70	3.11	0.21	0.00	0.00	0.00	1.7
	L41	0.19	13.04	0.69	2.84	21.24	0.17	0.04	0.65	0.18	0.02	0.87	1.19	0.00	0.01	0.03	4.46	48.95	5.26	0.00	0.20	0.00	0.00	1.6
	L42	0.10	17.10	0.69	4.12	21.59	0.13	0.02	0.54	0.18	0.02	0.72	0.99	0.00	0.02	0.03	3.33	46.12	4.19	0.09	0.02	0.00	0.00	1.3
	L31 red flashed	0.00	14.58	0.69	4.27	21.29	0.14	0.03	0.51	0.17	0.02	0.80	0.95	0.01	0.03	0.02	3.77	48.99	3.62	0.04	0.08	0.00	0.00	1.5
	L39	0.00	13.18	0.69	2.33	18.95	0.13	0.03	0.46	0.16	0.01	0.75	0.81	0.00	0.01	0.02	3.92	55.21	3.27	0.04	0.02	0.00	0.00	1.4
	L734	0.03	13.95	0.69	2.18	15.97	0.10	0.03	0.45	0.16	0.01	0.83	0.88	0.00	0.03	0.03	3.96	56.73	3.75	0.01	0.23	0.00	0.00	1.1
	L806	0.23	13.79	0.69	2.36	20.94	0.15	0.03	0.51	0.18	0.01	0.95	0.98	0.00	0.01	0.03	3.64	48.68	6.58	0.00	0.24	0.00	0.00	1.5
	L822	0.28	12.93	0.69	2.67	22.76	0.17	0.02	0.60	0.19	0.02	0.99	0.96	0.00	0.01	0.02	3.17	46.93	7.19	0.00	0.39	0.00	0.00	1.8
C15	L23	0.35	4.31	1.70	2.81	26.08	0.11	0.00	0.26	0.13	0.02	0.76	1.25	0.00	0.01	0.05	2.92	55.06	4.12	0.00	0.05	0.00	0.00	6.0
	L24	0.28	4.05	1.14	2.35	22.25	0.11	0.00	0.26	0.14	0.02	0.71	1.00	0.00	0.01	0.04	3.26	61.00	3.04	0.31	0.02	0.00	0.00	5.5
	L25	0.23	4.80	2.57	3.28	24.09	0.15	0.00	0.30	0.20	0.02	0.92	1.23	0.00	0.01	0.04	2.77	55.95	3.12	0.31	0.01	0.00	0.00	5.0
	L27	0.43	5.26	1.92	2.95	23.28	0.10	0.00	0.36	0.12	0.02	0.67	1.43	0.00	0.02	0.06	2.70	56.33	4.16	0.13	0.05	0.00	0.00	4.4
	L28	0.31	3.55	2.66	2.86	23.66	0.15	0.00	0.27	0.20	0.02	0.87	0.93	0.00	0.01	0.04	2.92	58.15	3.29	0.07	0.05	0.00	0.00	6.7
	L34 blue	0.50	4.64	2.34	3.16	24.18	0.16	0.01	0.31	0.17	0.01	0.78	1.53	0.23	0.11	0.05	1.74	56.60	3.21	0.10	0.01	0.00	0.00	5.2
	L29	0.48	3.42	1.89	2.72	22.02	0.12	0.00	0.20	0.26	0.03	1.13	0.99	0.00	0.01	0.04	3.21	60.55	2.62	0.30	0.00	0.00	0.00	6.4
	L30	0.58	2.60	3.62	4.05	25.69	0.20	0.00	0.21	0.20	0.02	0.99	1.11	0.00	0.00	0.04	2.73	53.93	3.27	0.74	0.00	0.00	0.00	9.9
	L37	0.26	4.37	1.29	1.92	22.98	0.11	0.00	0.27	0.20	0.01	0.89	1.00	0.00	0.00	0.04	3.60	57.51	5.42	0.02	0.10	0.00	0.00	5.3
	L38	0.42	3.93	2.76	3.29	24.37	0.11	0.00	0.30	0.16	0.02	0.70	1.24	0.00	0.00	0.04	1.93	56.77	3.72	0.22	0.00	0.00	0.00	6.2
	L702	0.34	4.68	2.64	3.21	22.71	0.10	0.01	0.24	0.15	0.02	0.72	0.99	0.00	0.00	0.04	2.72	58.00	3.26	0.16	0.00	0.00	0.00	4.9
	L714	0.57	3.87	1.07	1.56	21.26	0.07	0.00	0.14	0.17	0.02	0.75	0.72	0.00	0.00	0.04	3.82	63.73	1.95	0.23	0.00	0.00	0.00	5.5
	L719	0.43	2.93	2.33	2.97	23.24	0.08	0.00	0.15	0.16	0.01	0.73	0.90	0.00	0.00	0.03	2.46	60.38	2.89	0.32	0.00	0.00	0.00	7.9

APPENDIX 31 Data set RIEVAULX

Grous	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C13	R6	0.27	17.12	1.27	5.20	16.33	0.07	0.03	0.10	0.19	0.01	1.49	0.87	0.00	0.0	0.08	2.98	47.78	5.70	0.13	0.01	0.00	0.00	1.0
	R7	0.27	17.87	1.46	5.43	15.63	0.06	0.03	0.10	0.18	0.01	1.37	0.88	0.00	0.0	0.07	2.51	47.67	5.96	0.10	0.03	0.00	0.00	0.9
	R8	0.16	16.00	0.83	4.29	17.15	0.08	0.04	0.11	0.22	0.02	1.78	0.97	0.00	0.0	0.09	3.66	47.31	6.71	0.00	0.23	0.00	0.00	1.1
	R9	0.12	14.22	1.16	3.98	15.84	0.07	0.03	0.10	0.22	0.01	1.69	0.86	0.00	0.0	0.09	3.68	51.15	6.23	0.02	0.14	0.00	0.00	1.1
	R10	0.14	16.19	1.09	4.78	16.40	0.07	0.03	0.11	0.20	0.01	1.52	0.88	0.00	0.0	0.09	3.25	48.93	5.89	0.00	0.02	0.00	0.00	1.0
	R12	0.12	16.30	0.98	4.79	16.54	0.07	0.04	0.11	0.20	0.01	1.57	0.89	0.00	0.0	0.08	3.20	48.59	6.12	0.00	0.04	0.00	0.00	1.0
	R13	0.31	18.20	0.96	4.92	16.97	0.06	0.03	0.03	0.18	0.01	1.31	0.92	0.00	0.0	0.07	2.03	47.99	5.62	0.04	0.00	0.13	0.00	0.9
	R14	0.21	16.90	1.41	5.59	12.62	0.05	0.02	0.07	0.10	0.01	1.11	0.93	0.00	0.0	0.06	2.02	53.71	4.80	0.00	0.03	0.00	0.00	0.7
	R19	0.35	21.09	0.86	6.15	11.99	0.05	0.05	0.10	0.22	0.04	0.66	1.03	0.00	0.0	0.08	1.83	49.82	5.24	0.05	0.00	0.00	0.00	0.6
	R2 green	0.14	16.50	1.29	4.35	17.64	0.06	0.03	0.08	0.15	0.02	1.06	0.73	0.00	0.0	0.06	2.68	48.78	5.63	0.20	0.22	0.00	0.00	1.1
	R58 murrey	0.26	13.54	0.87	5.77	15.00	0.13	0.04	0.30	0.12	0.01	0.74	1.63	0.00	0.0	0.08	1.72	50.42	8.56	0.00	0.42	0.00	0.00	1.1
	R62	0.15	14.72	0.80	4.10	17.27	0.07	0.03	0.13	0.21	0.02	1.49	1.03	0.00	0.0	0.08	2.96	50.24	6.08	0.00	0.24	0.00	0.00	1.2
C13/14	R17	0.30	16.26	0.96	4.82	14.99	0.08	0.03	0.30	0.13	0.01	0.91	1.38	0.00	0.09	0.07	3.28	50.37	5.44	0.01	0.23	0.00	0.00	0.9
	R44 murrey	0.16	15.29	0.82	4.85	14.40	0.14	0.04	0.11	0.09	0.01	0.65	1.95	0.00	0.0	0.08	2.03	55.05	3.92	0.00	0.07	0.00	0.00	0.9
C14a	R4	0.25	16.51	1.65	5.42	19.38	0.08	0.03	0.12	0.14	0.02	1.15	0.78	0.00	0.0	0.08	2.65	45.49	5.73	0.15	0.01	0.00	0.00	1.2
	R5	0.34	16.64	1.89	5.41	16.86	0.07	0.04	0.07	0.18	0.02	1.29	0.84	0.00	0.0	0.07	2.55	47.89	5.36	0.10	0.01	0.00	0.00	1.0
	R20	0.30	16.57	1.37	6.47	16.18	0.06	0.02	0.07	0.09	0.01	1.27	0.93	0.00	0.1	0.07	1.95	49.01	5.16	0.05	0.00	0.00	0.00	1.0
	R36	0.14	17.03	1.10	5.14	17.27	0.08	0.04	0.11	0.19	0.01	1.59	0.96	0.00	0.0	0.08	3.05	46.55	6.26	0.00	0.03	0.00	0.00	1.0
	R46	0.20	15.56	1.92	6.04	21.22	0.10	0.04	0.11	0.18	0.01	1.25	0.96	0.00	0.0	0.09	2.66	43.85	5.34	0.08	0.02	0.00	0.00	1.4
	R1 amber	0.21	15.69	1.57	6.13	21.13	0.10	0.03	0.11	0.17	0.01	1.22	0.95	0.00	0.0	0.09	2.62	44.08	5.38	0.09	0.02	0.00	0.00	1.3
	R53 blue	0.29	16.72	1.35	5.40	17.04	0.10	0.04	0.19	0.17	0.01	1.77	1.82	0.15	0.3	0.43	1.98	44.47	6.33	0.00	1.04	0.00	0.01	1.0
C14b	R3	0.08	12.81	0.79	2.59	16.22	0.06	0.03	0.11	0.21	0.01	1.50	0.88	0.00	0.0	0.08	3.21	54.23	6.70	0.00	0.11	0.00	0.00	1.3
	R11	0.35	13.63	1.41	4.93	13.77	0.07	0.03	0.11	0.14	0.01	1.07	1.52	0.00	0.1	0.09	2.92	52.66	6.38	0.00	0.49	0.00	0.00	1.0
	R26	0.25	14.47	1.01	4.88	13.90	0.07	0.02	0.13	0.11	0.01	0.86	1.21	0.00	0.2	0.08	2.43	55.08	4.17	0.00	0.81	0.00	0.00	1.0
	R35	0.26	14.08	1.18	5.00	16.17	0.12	0.03	0.23	0.14	0.01	1.16	1.64	0.00	0.1	0.13	2.55	49.24	7.40	0.00	0.20	0.00	0.00	1.1
	R45 green	0.33	11.72	1.49	3.45	18.83	0.08	0.04	0.15	0.15	0.01	1.40	0.98	0.00	0.0	0.06	3.09	51.06	6.64	0.00	0.15	0.00	0.00	1.6
	R50 striated red	0.22	12.81	0.93	3.10	14.06	0.09	0.04	0.13	0.11	0.01	0.74	1.09	0.00	0.2	0.03	2.29	59.54	3.94	0.00	0.30	0.00	0.01	1.1
	R51 blue	0.46	12.15	1.17	2.97	16.12	0.10	0.03	0.15	0.16	0.01	2.08	1.40	0.12	0.3	0.25	2.31	50.54	7.92	0.00	0.81	0.00	0.03	1.3
	R52 blue	0.51	11.48	0.84	2.85	15.05	0.10	0.03	0.19	0.17	0.02	2.14	1.39	0.12	0.2	0.26	2.60	52.87	7.79	0.00	1.00	0.00	0.04	1.3
	R63 blue	0.17	15.41	1.69	4.86	16.16	0.05	0.03	0.06	0.12	0.01	1.53	1.02	0.14	0.5	0.53	1.98	49.79	4.84	0.23	0.50	0.15	0.01	1.0
C14c	R24	0.34	12.95	1.86	5.89	15.13	0.06	0.02	0.16	0.11	0.01	1.02	0.97	0.00	0.1	0.05	2.54	53.95	4.36	0.00	0.17	0.00	0.00	1.2
	R25	0.29	11.47	1.69	6.48	14.73	0.09	0.02	0.10	0.16	0.01	1.14	1.48	0.00	0.1	0.07	1.65	55.53	4.48	0.00	0.20	0.00	0.00	1.3
	R55 green	0.23	14.17	1.69	5.75	12.18	0.07	0.02	0.11	0.11	0.01	0.89	1.11	0.00	3.4	0.29	2.52	51.67	4.44	0.00	0.74	0.00	0.26	0.9
	R56 green	0.23	14.93	2.18	6.83	12.80	0.05	0.01	0.12	0.12	0.01	0.84	1.10	0.00	3.0	0.25	2.27	49.95	4.24	0.00	0.54	0.00	0.17	0.9
	R54 green	0.24	12.06	2.35	5.09	15.11	0.08	0.02	0.13	0.10	0.01	0.76	1.00	0.00	3.2	0.38	2.64	52.48	3.71	0.02	0.20	0.00	0.08	1.3
C15a	R15	0.34	11.37	1.61	5.67	14.42	0.10	0.02	0.10	0.16	0.01	1.10	1.54	0.00	0.0	0.07	1.60	56.57	4.70	0.00	0.21	0.00	0.00	1.3
	R18	0.39	9.97	0.79	3.49	13.94	0.09	0.02	0.07	0.16	0.01	1.08	1.43	0.00	0.1	0.07	1.92	60.67	5.24	0.00	0.24	0.00	0.00	1.4
	R23	0.35	11.96	1.41	4.70	14.79	0.09	0.02	0.11	0.16	0.01	1.25	1.42	0.00	0.1	0.08	2.41	54.24	6.17	0.00	0.35	0.00	0.00	1.2
	R29	0.39	11.91	1.91	6.34	13.80	0.08	0.02	0.10	0.14	0.01	1.02	1.25	0.00	0.1	0.07	1.79	56.39	4.14	0.02	0.16	0.00	0.00	1.2
	R30	0.43	11.30	1.66	5.27	14.70	0.10	0.02	0.10	0.16	0.01	1.18	1.58	0.00	0.0	0.08	1.59	55.44	5.67	0.00	0.30	0.00	0.00	1.3
	R31	0.25	11.98	1.29	5.45	14.79	0.10	0.02	0.11	0.16	0.01	1.25	1.45	0.00	0.1	0.08	1.72	55.34	5.07	0.00	0.46	0.00	0.00	1.2
C15b	R21	0.46	12.88	1.02	3.05	18.80	0.08	0.02	0.34	0.18	0.01	1.44	1.54	0.00	0.0	0.10	3.41	45.79	10.10	0.00	0.40	0.00	0.00	1.5
C15c	R22	0.16	6.75	1.57	2.76	25.65	0.18	0.01	0.33	0.13	0.01	0.61	1.96	0.00	0.0	0.04	4.73	50.65	4.03	0.00	0.07	0.00	0.00	3.8
	R27	0.18	6.03	2.15	4.35	23.93	0.13	0.01	0.40	0.15	0.01	0.91	2.01	0.00	0.0	0.06	2.42	53.08	3.72	0.08	0.02	0.00	0.00	4.0
	R28	0.18	6.56	1.49	3.45	24.30	0.16	0.01	0.37	0.09	0.01	0.71	1.97	0.00	0.0	0.03	4.11	52.64	3.54	0.00	0.01	0.00	0.00	3.7
	R38	0.17	6.36	1.26	3.05	22.89	0.16	0.01	0.35	0.10	0.01	0.67	1.73	0.00	0.0	0.02	4.43	55.11	3.32	0.00	0.00	0.00	0.00	3.6
	R39	0.23	6.10	0.95	2.66	22.21	0.15	0.01	0.35	0.10	0.01	0.66	1.67	0.00	0.0	0.02	4.71	57.05	2.76	0.00	0.00	0.00	0.00	3.6
	R41	0.20	6.45	1.49	3.00	22.39	0.14	0.01	0.32	0.09	0.01	0.65	1.76	0.00	0.0	0.03	4.28	55.58	3.23	0.00	0.01	0.00	0.00	3.5
	R43	0.23	7.12	1.24	2.32	23.60	0.17	0.01	0.31	0.13	0.01	0.78	2.20	0.00	0.0	0.04	4.88	51.17	5.27	0.00	0.15	0.00	0.00	3.3
	R32 SS	0.22	6.06	1.51	3.85	23.87	0.17	0.01	0.27	0.12	0.01	0.81	1.98	0.00	0.0	0.03	4.52	51.82	4.39	0.00	0.01	0.00	0.00	3.9
	R33 SS	0.22	6.05	0.98	2.96	24.53	0.17	0.01	0.28	0.12	0.01	0.64	2.38	0.00	0.0	0.04	4.61	52.58	4.03	0.00	0.05	0.00	0.00	4.1
	R37 SS	0.28	6.28	2.11	3.70	25.99	0.18	0.01	0.34	0.14	0.01	0.87	2.16	0.00	0.0	0.04	4.12	48.35	4.95	0.00	0.11	0.00	0.00	4.1
	R60	0.18	7.31	1.86	3.91	23.57	0.17	0.01	0.29	0.11	0.01	0.63	2.13	0.00	0.0	0.03	4.52	50.52	4.36	0.00	0.01	0.00	0.00	3.2
	R61	0.20	7.28	1.21	2.64	23.26	0.18	0.01	0.29	0.12	0.01	0.72	2.20	0.00	0.0	0.04	4.98	51.15	5.29	0.00	0.07	0.00	0.00	3.2
C15d	R40	0.22	4.33	2.54	3.22	20.57	0.08	0.00	0.36	0.32	0.03	0.71	1.01	0.00	0.0	0.03	2.00	61.12	2.88	0.22	0.02	0.00	0.00	4.8
	R42	0.44	4.80	1.87	2.27	22.38	0.07	0.01	0.09	0.15	0.02	0.70	0.68	0.00	0.0	0.03	3.56	59.95	2.56	0.06	0.00	0.00	0.00	4.7
	R48 fl. Red	0.36	6.32	2.12	1.92	22.01	0.07	0.01	0.08	0.14	0.02	0.54	0.70	0.00	0.0	0.03	3.64	58.09	3.49	0.00	0.06	0.00	0.00	3.5
	R34 SS	0.48	4.70	2.44	2.77	21.70	0.10	0.00	0.25	0.30	0.04	0.86	0.83	0.00	0.0	0.03	2.42	60.14	2.78	0.15	0.02	0.00	0.00	4.6

APPENDIX 32 Data set WHITBY

Group	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	Rb2O	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	PbO	Sb2O5	SnO2	Ca:K
C13a	W1	0.29	14.68	1.64	7.42	16.81	0.11	0.04	0.14	0.12	0.01	1.02	1.94	0.01	0.05	0.10	3.05	47.37	4.98	0.16	0.05	0.00	0.00	1.1
	W4	0.21	13.61	1.90	8.02	15.27	0.11	0.03	0.18	0.11	0.01	0.98	1.61	0.02	0.08	0.10	1.82	50.82	4.89	0.09	0.15	0.00	0.00	1.1
	W5	0.31	16.36	1.06	6.94	14.32	0.09	0.03	0.12	0.09	0.01	0.47	1.67	0.00	0.01	0.05	1.17	52.37	4.88	0.04	0.00	0.00	0.00	0.9
	W9	0.23	14.89	2.32	7.40	15.35	0.11	0.03	0.17	0.12	0.01	1.08	1.63	0.01	0.11	0.10	1.76	49.30	4.69	0.00	0.67	0.00	0.03	1.0
	W27 blue	0.24	14.99	1.82	5.75	13.16	0.12	0.06	0.14	0.13	0.01	1.51	1.51	0.16	0.31	0.32	2.05	51.76	5.54	0.25	0.17	0.00	0.00	0.9
	W31	0.48	18.12	1.39	6.25	16.30	0.07	0.03	0.12	0.12	0.01	1.01	1.42	0.00	0.03	0.09	1.99	46.68	5.71	0.07	0.10	0.00	0.00	0.9
C13b	W2	0.33	11.98	1.60	4.89	12.70	0.10	0.03	0.16	0.13	0.01	1.30	1.64	0.00	0.03	0.15	2.42	56.27	4.09	2.14	0.04	0.00	0.00	1.1
	W3	0.27	14.62	0.98	4.92	12.40	0.07	0.03	0.12	0.12	0.02	0.66	1.05	0.00	0.02	0.07	1.79	57.39	4.92	0.45	0.10	0.00	0.00	0.8
	W6	0.60	12.90	1.03	3.49	14.14	0.08	0.03	0.14	0.23	0.03	1.49	1.26	0.00	0.01	0.09	2.73	54.79	6.58	0.00	0.38	0.00	0.00	1.1
	W10	0.22	14.86	0.87	3.85	14.62	0.04	0.02	0.05	0.12	0.01	0.69	0.60	0.00	0.01	0.05	1.76	57.01	4.30	0.89	0.01	0.00	0.00	1.0
C14a	W8	0.28	9.33	0.85	1.16	12.88	0.12	0.04	0.15	0.15	0.01	1.00	1.21	0.00	0.04	0.04	4.04	60.49	7.76	0.27	0.19	0.00	0.00	1.4
C14b	W11	0.22	15.49	2.04	8.21	16.28	0.07	0.02	0.10	0.09	0.01	0.75	0.90	0.00	0.02	0.08	1.52	49.71	4.42	0.06	0.03	0.00	0.00	1.1
	W15	0.23	15.27	1.07	5.22	16.90	0.08	0.02	0.25	0.11	0.01	0.86	1.33	0.00	0.11	0.07	2.28	50.68	5.12	0.00	0.38	0.00	0.01	1.1
	W25 striated red	0.24	15.50	1.49	6.60	18.22	0.15	0.05	0.27	0.18	0.01	1.45	1.67	0.00	0.12	0.10	2.55	45.92	5.20	0.24	0.01	0.00	0.00	1.2
	W26 striated red	0.22	14.80	1.43	6.81	17.10	0.13	0.04	0.25	0.16	0.01	1.26	1.49	0.00	0.17	0.08	2.71	47.69	5.44	0.17	0.02	0.00	0.00	1.2
C14c	W7	0.87	12.56	0.97	2.26	19.56	0.14	0.03	0.18	0.20	0.02	1.79	1.45	0.01	0.24	0.09	2.95	43.94	10.45	0.07	2.12	0.00	0.10	1.6
C14d	W17 SS	0.28	12.44	1.04	4.16	18.69	0.05	0.02	0.06	0.10	0.01	0.87	0.61	0.00	0.03	0.03	1.47	55.77	4.02	0.21	0.13	0.00	0.00	1.5
	W18 SS	0.23	13.45	1.13	3.98	17.14	0.06	0.03	0.07	0.11	0.01	1.01	0.59	0.00	0.04	0.05	1.86	54.39	4.39	1.11	0.35	0.00	0.00	1.3
	W19 SS	0.18	12.61	1.36	4.46	18.68	0.05	0.02	0.06	0.11	0.01	0.96	0.60	0.01	0.04	0.03	1.61	54.63	4.36	0.03	0.19	0.00	0.00	1.5
	W28 blue	0.28	11.44	0.84	2.91	15.75	0.07	0.01	0.04	0.15	0.01	1.52	0.63	0.06	0.10	0.21	3.26	58.48	3.22	0.93	0.10	0.00	0.00	1.4
C15a	W16	0.18	9.22	1.73	6.99	17.03	0.07	0.01	0.16	0.10	0.01	0.62	1.69	0.01	0.02	0.06	1.41	57.55	3.02	0.03	0.10	0.00	0.00	1.8
	W13 SS	0.15	10.93	1.81	6.48	16.11	0.07	0.02	0.18	0.10	0.01	0.73	1.72	0.01	0.02	0.06	1.81	55.80	3.67	0.20	0.11	0.00	0.00	1.5
	W14 SS	0.39	11.64	1.81	6.23	15.38	0.07	0.03	0.09	0.11	0.01	0.85	1.51	0.00	0.07	0.07	1.45	55.36	4.26	0.52	0.14	0.00	0.00	1.3
	W20 SS	0.31	11.81	2.49	6.54	13.28	0.06	0.04	0.06	0.17	0.02	0.95	1.05	0.00	0.01	0.04	1.95	57.55	3.47	0.16	0.06	0.00	0.00	1.1
C15b	W21 fl. Red clear	0.12	10.15	1.39	5.75	17.03	0.08	0.02	0.18	0.15	0.01	1.14	1.93	0.00	0.02	0.07	2.96	53.19	5.14	0.42	0.25	0.00	0.00	1.7
	W24 fl. Red clear	0.00	8.52	0.91	4.57	14.32	0.08	0.02	0.36	0.17	0.01	0.68	1.50	0.00	0.01	0.07	2.31	60.17	4.04	2.24	0.02	0.00	0.00	1.7
C15c	W22	0.32	4.31	2.43	3.16	23.54	0.11	0.00	0.26	0.17	0.02	0.80	0.79	0.00	0.00	0.03	2.25	58.03	3.00	0.76	0.00	0.00	0.00	5.5
	W30	0.38	3.48	3.31	3.27	24.33	0.17	0.00	0.15	0.19	0.02	1.14	1.00	0.00	0.01	0.04	3.74	54.69	2.94	1.16	0.00	0.00	0.00	7.0
	W33	0.06	5.52	1.01	2.43	22.96	0.06	0.01	0.04	0.21	0.02	1.97	0.40	0.01	0.01	0.03	3.20	58.74	2.86	0.39	0.07	0.00	0.00	4.2

APPENDIX 33 Regional compositions

High %	Low %	Region/country	Ca:K	Area	Sub-band	Source
Na, Mg, K, P	Si, Al	France	1	C13 NW	**A1**	Gratuze, unpublished
Na, Mg	Si		1.1	C13 NC	**A2**	Gratuze, unpublished
Na, Mg,			0.9	C14 NW	**A3**	Gratuze, unpublished
K	Na		0.9	C13 NC	**B**	Gratuze, unpublished
Mg, Si	Mn		1.1	C13 NC	**C1**	Gratuze, unpublished
Na, Si	Mn		1.1	C14 NW	**C2**	Barrera & Velde, 1989
Mg, K	Ca		0.9	C14 NC	**C3**	Barrera & Velde, 1989
Na, Mg, K	Ca, Al		0.7	C14 NW	**D**	Barrera & Velde, 1989
Mg, Si	Al, P, K, Mn		1.2	C15 NW	**E1**	Gratuze, unpublished
Na, Mg	Al, P, K, Mn		1.1	C15 NC	**E2**	Barrera & Velde, 1989
Ca	Na, Mg, K, Mn		1.5	C14 E	**F1**	Barrera & Velde, 1989
Ca, Mn	Na, K,		1.4	C14 E	**F2**	Barrera & Velde, 1989
Na, Mg, P	K	England	1.6	C13/14 ST	**E ST**	Mortimer, 1997; Paynter in publication
Na, Mg, Mn	K		1.4	C14 ST	**E ST**	Paynter, in publication
Na, Mg, Mn	K		1.5	C15 ST	**E ST**	Freestone et al
Na, Mg, Mn	K		1.1	C15/16	**E ST**	Paynter, in publication
Na, Mg, Mn	K, Ca		1.1	C16 ST early	**E ST**	Meek, 2011
Na, Mg. Mn	K, Ca		1.1	C16 ST mid	**E ST**	Meek, 2011
Na, Mg	Al, K, Ca		1.2	C14 TW	**E TW**	Meek, Paynter/Dungworth, Merchant, Welham
K, Ca, Mn	Na, Si, P	Germany	1.2	C13 GER	**G A**	Wedepohl 1997
Al, P, Ca	Na, Si, K		1.7	C15 GER	**G B1**	Wedepohl 1997
Al, P, Ca	Na, Si, K		2.4	C14 GER	**G B2**	Wedepohl, 1997
Na, P, Ca	K		4.5	C15 GER	**G C**	Wedepohl 1997, Wedepohl & Simon, 2010
K, Ca	Na, Si, P	Central Europe	0.8	C14 BOH	**BOH A**	Wedepohl 1997, Cilova, Kucerova, Knizova, Trojek 2014/15?
K	Na, Al, P, Mn		0.8	C15 BOH	**BOH B**	Cilova & Woitsch 2012

APPENDIX 34 Precision and accuracy ALCESTER

	Alcester																								
	Normalised	Cl	K2O	Na2O	MgO	CaO	Sr	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Corning B	Average	0.14	0.92	17.03	1.03	8.69		0.02	0.10	0.02	0.37	0.26	0.05	2.67	0.20	4.37	62.07	0.82	0.52	0.15	0.00	0.48
	Stdev	0.01	0.02	0.40	0.09	0.09		0.01	0.00	0.00	0.00	0.01	0.00	0.03	0.00	0.03	0.33	0.03	0.05	0.07	0.00	0.01
	B Known		1.00	17.00	1.03	8.56		0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.50	0.46	0.04	0.61
	RSD Precision	5.45	2.12	2.37	8.53	1.03		23.17	1.24	9.89	1.18	2.08	0.70	1.31	0.98	0.76	0.53	3.21	8.75	45.09	#DIV/0!	2.18
	Accuracy		7.92	-0.17	-0.18	-1.50		81.98	-17.62	21.14	-8.37	-2.91	-3.16	-0.19	-6.82	-0.17	-0.89	-0.17	-4.08	67.96	100.00	21.88
Corning D	Average	0.14	11.29	1.20	3.94	15.60		0.24	0.38	0.01	0.58	0.63	0.02	0.38	0.10	5.29	54.72	3.93	0.10	1.01	0.10	0.29
	Stdev	0.01	0.03	0.11	0.09	0.06		0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.04	0.02	0.04	0.04	0.01
	D Known		11.3	1.2	3.94	14.8		0.291	0.38	0.0125	0.52	0.55	0.023	0.38	0.1	5.3	55.24	3.93	0.23	0.97	0.1	0.241
	RSD Precision	9.95	0.26	9.46	2.32	0.37		3.21	0.62	4.32	0.44	0.41	3.31	0.70	1.56	1.86	0.13	1.05	17.36	3.49	35.64	2.08
	Accuracy		0.06	0.13	0.13	-5.39		16.05	1.26	5.86	-11.22	-15.17	6.76	0.83	-4.50	0.13	0.94	0.13	54.86	-3.93	-0.37	-19.68
	RSD	calculated as: (standard deviation/mean)*100																				
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																				

APPENDIX 35 Precision and accuracy BARDNEY

Bardney Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
CL330	Average		1.41	8.53	6.38	22.84	0.02			0.21	0.34		0.09		0.11	4.35	55.02	0.49		0.21		
	StdDev		0.03	0.97	0.60	0.71	0.00			0.01	0.01		0.00		0.00	0.22	1.08	0.00		0.00		
	CL 330 known		1.50	9.50	6.60	21.90	0.02			0.20	0.30		0.09		0.10	4.30	55.40					
	RSD		2.01	11.33	9.37	3.11	6.52			5.43	2.80		2.96		2.24	5.16	1.96	0.12		0.12		
	Accuracy		6.29	10.26	3.39	-4.29	-13.78			-2.84	-12.74		3.69		-12.68	-1.26	0.69					
Corning A	Average		2.64	14.25	2.73	4.95	0.11	0.39	0.74		1.15	1.09	0.18	1.16	0.05	1.02	67.12	0.50	0.15	1.55	0.08	0.07
	StdDev		0.01	0.09	0.10	0.04	0.00	0.01	0.00		0.00	0.00	0.00	0.02	0.00	0.02	0.10	0.00	0.01	0.20	0.02	0.00
	A Known		2.87	14.30	2.66	5.03	0.10	0.56	0.79		1.09	1.00	0.17	1.17	0.04	1.00	66.76	0.13	0.10	1.75	0.19	0.12
Bardney	RSD		0.28	0.65	3.80	0.75	4.40	1.74	0.62		0.14	0.20	0.91	1.68	1.07	1.51	0.15	0.10	4.01	13.09	24.29	1.25
Corning A	Accuracy		7.92	0.32	-2.75	1.52	-8.19	29.67	6.51		-5.87	-8.75	-7.37	1.23	-8.63	-1.69	-0.54	-281.18	-45.69	11.17	55.62	41.70
Corning B	Average	0.11	0.95	17.59	0.85	8.72	0.02	0.02	0.12	0.02	0.37	0.26	0.05	2.70	0.20	4.31	61.47	0.85	0.44	0.39	0.04	0.46
	StdDev	0.01	0.05	0.34	0.11	0.09	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.09	0.25	0.06	0.03	0.09	0.03	0.03
	Known		1.00	17.00	1.03	8.56	0.02	0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.50	0.46	0.04	0.61
	RSD	7.06	4.85	1.91	12.48	1.06	11.41	42.03	4.11	25.31	1.24	1.59	1.94	1.52	1.54	1.98	0.41	7.10	5.76	24.21	74.15	5.62
	Accuracy		5.29	-3.45	17.37	-1.83	12.70	84.86	-29.35	33.99	-8.16	-3.36	-0.54	-1.32	-5.21	1.11	0.08	-3.90	12.58	15.07	-3.83	24.58
Corning C	Average		2.36	1.32	3.04	4.75	0.30	11.16	1.16	0.06	0.32	0.01	0.18	1.09	0.03	0.88	35.36	0.49	0.00	0.25	0.00	37.21
	StdDev	0.00	0.03	0.28	0.13	0.04	0.01	0.05	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.12	0.00	0.00	0.07	0.00	0.21
	C Known		2.84	1.07	2.76	5.07	0.29	11.40	0.79	0.01	0.34	0.00	0.18	1.13	0.05	0.87	35.88	0.14	0.10	0.03	0.19	36.70
	RSD	9.84	1.07	20.99	4.31	0.82	3.64	0.49	1.35	11.82	0.29	15.35	1.76	0.31	2.78	2.42	0.35	0.09		27.57		0.57
	Accuracy		16.99	-23.53	-10.27	6.24	-2.07	2.11	-46.35	-1176.03	6.99		-1.27	3.35	44.37	-0.82	1.45	-247.91	100.00	-749.18	100.00	-1.40
Corning D chunk	Average		11.18	1.25	3.79	15.34	0.06	0.24	0.40	0.01	0.58	0.63	0.02	0.40	0.10	5.30	54.76	3.63	0.00	1.93	0.03	0.28
Bardney	StdDev		0.04	0.18	0.10	0.07	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.08	0.08	0.10	0.00	0.08	0.00	0.00
	D chunk Known		11.30	1.20	3.94	14.80	0.06	0.29	0.38	0.01	0.52	0.55	0.02	0.38	0.10	5.30	55.24	3.93	0.23	0.97	0.10	0.24
	RSD		0.37	14.63	2.76	0.43	1.13	3.46	0.25	14.09	1.08	1.09	8.47	0.39	0.27	1.52	0.14	2.77		4.02	6.77	1.44
	Accuracy		1.09	-4.51	3.84	-3.66	-11.63	18.87	-6.28	13.27	-12.38	-14.51	10.37	-5.64	-4.19	0.01	0.87	7.65	100.00	-99.22	66.42	-14.99
Corning D	Average		11.36	1.23	3.93	15.63	0.06	0.22	0.41	0.01	0.58	0.63	0.02	0.38	0.10	5.21	54.57	3.89	0.05	1.22	0.05	0.28
	StdDev		0.11	0.20	0.20	0.18	0.00	0.03	0.02	0.00	0.01	0.01	0.00	0.01	0.00	0.13	0.37	0.15	0.03	0.44	0.04	0.01
	D Known		11.30	1.20	3.94	14.80	0.06	0.29	0.38	0.01	0.52	0.55	0.02	0.38	0.10	5.30	55.24	3.93	0.23	0.97	0.10	0.24
	RSD		1.00	15.86	5.11	1.17	2.33	13.94	3.67	16.70	1.25	1.11	12.34	1.31	1.80	2.56	0.68	3.83	46.16	36.14	90.30	1.96
	Accuracy		-0.51	-2.66	0.13	-5.62	-13.07	23.27	-8.62	21.91	-11.38	-14.68	10.63	-1.00	-3.57	1.69	1.21	1.09	76.33	-26.02	53.06	-17.57
HE Tender	Average		5.60	1.00	2.89	19.89	0.11	0.17	0.33	0.05	0.96	1.42				1.97	63.14	1.82				
	StdDev		0.04	0.20	0.06	0.11	0.00	0.02	0.01	0.00	0.01	0.01				0.02	0.18	0.07				
	HE T Known		5.80	0.86	3.06	19.69	0.11	0.23	0.27	0.05	0.87	1.36				2.05	63.70	1.88				
	RSD		0.64	20.34	2.14	0.57	2.28	10.30	3.35	2.01	0.83	0.88				0.96	0.29	3.59				
	Accuracy		3.39	-16.81	5.57	-1.02	-1.17	28.05	-20.62	6.23	-10.50	-4.49				3.96	0.88	3.40				
	RSD	calculated as: (standard deviation/mean)*100																				
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																				

APPENDIX 36 Precision and accuracy BORDESLEY

		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
	CL330 ave	0.01	1.40	8.81	6.31	22.65	0.02	0.00	0.00	0.20	0.33	0.00	0.09	0.00	0.11	4.43	55.15	0.48	0.00	0.00	0.00	0.00
	CL330 std	0.01	0.02	0.26	0.11	0.22	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.05	0.23	0.00	0.00	0.00	0.00	0.00
	Known	0.000	1.500	9.500	6.600	21.900	0.020	0.000	0.000	0.200	0.300	0.000	0.090	0.000	0.100	4.300	55.400	0.000	0.000	0.000	0.000	0.000
	RSD Precision		1.31	2.96	1.68	0.97	2.67			2.90	1.73		2.37		2.13	1.18	0.43						
	Accuracy		6.44	7.31	4.46	-3.44	-14.99			0.04	-11.45		4.79		-12.54	-3.03	0.44						
	Corn A ave	0.05	2.68	14.44	2.70	5.01	0.11	0.41	0.77	0.00	1.18	1.11	0.19	1.16	0.05	1.01	67.87	0.49	0.15	0.49	0.05	0.07
	Com Stdev	0.01	0.02	0.36	0.10	0.03	0.01	0.01	0.00	0.00	0.01	0.01	0.00	0.02	0.00	0.02	0.31	0.00	0.00	0.12	0.05	0.00
	Known		2.870	14.300	2.660	5.030	0.100	0.560	0.790	0.000	1.090	1.000	0.170	1.170	0.044	1.000	66.760	0.130	0.100	1.750	0.190	0.120
	RSD Precision		0.73	2.46	3.55	0.66	6.75	2.23	0.53		0.80	0.57	1.64	1.74	1.34	1.60	0.46	0.07	3.11	24.12	102.43	3.26
	Accuracy		6.73	-0.99	-1.64	0.44	-8.48	27.59	2.07		-8.21	-10.88	-10.45	0.66	-11.17	-1.47	-1.66	-277.17	-50.45	72.18	76.17	40.40
Chunk	Com B Chu	0.00	0.96	15.88	0.81	9.53	0.02	0.02	0.13	0.03	0.43	0.29	0.05	3.63	0.24	4.26	61.78	0.86	0.07	0.31	0.00	0.58
	Com B Std	0.00	0.01	0.42	0.15	0.10	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.05	0.00	0.06	0.40	0.11	0.03	0.09	0.00	0.01
	Known	0.000	1.000	17.000	1.030	8.560	0.019	0.120	0.089	0.025	0.340	0.250	0.046	2.660	0.190	4.360	61.520	0.820	0.500	0.460	0.040	0.610
	RSD Precision		0.89	2.62	18.06	1.02	8.43	41.00	5.49	5.82	0.12	1.13	2.96	1.28	1.16	1.43	0.64	13.01	35.86	28.28		1.97
	Accuracy		3.67	6.58	21.56	-11.36	-12.63	80.70	-44.57	-8.95	-25.41	-17.01	-14.29	-36.60	-24.20	2.22	-0.42	-5.36	85.69	32.20	100.00	5.40
Mounted	Corn B Ave	0.11	0.94	17.35	0.88	8.78	0.02	0.02	0.12	0.02	0.37	0.26	0.05	2.68	0.20	4.34	61.91	0.83	0.44	0.08	0.04	0.48
	Com B Std	0.01	0.04	0.28	0.08	0.08	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.07	0.01	0.08	0.24	0.04	0.02	0.04	0.03	0.03
	Known	0.000	1.000	17.000	1.030	8.560	0.019	0.120	0.089	0.025	0.340	0.250	0.046	2.660	0.190	4.360	61.520	0.820	0.500	0.460	0.040	0.610
	RSD Precision		4.01	1.62	9.33	0.95	9.73	40.26	3.70	20.29	1.62	1.62	2.44	2.48	2.61	1.77	0.39	5.31	4.94	48.47	79.72	6.01
	Accuracy		6.20	-2.05	14.63	-2.56	8.54	85.07	-34.01	27.48	-9.27	-4.12	-1.53	-0.78	-6.93	0.38	-0.63	-1.31	12.02	82.36	3.93	21.96
	Corn C Ave	0.03	2.34	1.27	2.94	4.75	0.30	11.22	1.12	0.07	0.32	0.00	0.18	1.07	0.03	0.85	34.88	0.48	0.00	0.01	0.26	37.86
	Com C Std	0.01	0.03	0.28	0.09	0.04	0.01	0.07	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.03	0.68	0.00	0.00	0.02	0.32	0.60
	Known	0.000	2.840	1.070	2.760	5.070	0.290	11.400	0.790	0.005	0.340	0.000	0.180	1.130	0.052	0.870	35.880	0.140	0.100	0.030	0.190	36.700
	RSD Precision		1.28	22.22	3.02	0.91	3.70	0.63	7.51	10.40	0.69		1.58	0.31	2.39	2.96	1.94	0.06		244.95	120.93	1.57
	Accuracy		17.66	-18.33	-6.40	6.32	-4.83	1.56	-42.22	-1230.06	6.54		-1.33	5.07	43.34	2.07	2.78	-240.21	100.00	72.31	-38.49	-3.17
Chunk	Com D Chu	0.00	11.28	1.26	3.72	15.58	0.06	0.24	0.42	0.01	0.59	0.64	0.02	0.40	0.11	5.36	55.61	3.61	0.00	0.71	0.03	0.28
	Com D Std	0.00	0.05	0.18	0.10	0.07	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.08	0.10	0.10	0.00	0.03	0.00	0.00
	Known	0.000	11.300	1.200	3.940	14.800	0.057	0.291	0.380	0.013	0.520	0.550	0.023	0.380	0.100	5.300	55.240	3.930	0.230	0.970	0.100	0.241
	RSD Precision		0.41	14.40	2.72	0.47	1.13	3.48	0.21	14.11	1.12	1.13	8.51	0.43	0.24	1.49	0.18	2.72		4.57	6.81	1.48
	Accuracy		0.15	-4.85	5.54	-5.28	-13.37	17.60	-11.62	11.92	-14.13	-16.30	8.98	-5.01	-5.81	-1.08	-0.67	8.17	100.00	26.77	65.90	-16.78
Mounted	Corn D Ave	0.09	11.41	1.26	3.86	15.79	0.07	0.23	0.43	0.01	0.59	0.64	0.02	0.38	0.11	5.23	55.06	3.88	0.06	0.49	0.05	0.29
	Com D Std	0.015	0.098	0.188	0.143	0.158	0.002	0.021	0.011	0.001	0.010	0.010	0.002	0.008	0.003	0.115	0.262	0.114	0.021	0.152	0.040	0.008
	Known	0.000	11.300	1.200	3.940	14.800	0.057	0.291	0.380	0.013	0.520	0.550	0.023	0.380	0.100	5.300	55.240	3.930	0.230	0.970	0.100	0.241
	RSD Precision		0.86	14.94	3.71	1.00	3.66	9.11	2.51	13.26	1.71	1.49	8.39	1.99	2.46	2.20	0.48	2.93	32.05	31.19	81.11	2.80
	Accuracy		-0.97	-4.74	1.92	-6.66	-15.73	19.44	-12.56	14.76	-12.77	-16.46	8.15	-0.30	-5.39	1.27	0.32	1.22	72.11	49.88	51.22	-20.23
	HE2 avera	0.06	5.56	1.01	2.90	19.93	0.11	0.16	0.34	0.04	0.96	1.42	0.01	0.01	0.02	1.93	63.42	1.78	0.30	0.00	0.00	0.03
	HE2 Stdev	0.012	0.042	0.178	0.113	0.117	0.002	0.016	0.011	0.001	0.010	0.012	0.001	0.001	0.001	0.040	0.165	0.061	0.017	0.000	0.000	0.001
	Known	0.000	5.800	0.860	3.060	19.690	0.110	0.230	0.270	0.048	0.870	1.360	0.000	0.000	0.000	2.050	63.700	1.880	0.000	0.000	0.000	0.000
	RSD Precision		0.76	17.69	3.91	0.59	1.79	9.87	3.18	2.35	1.06	0.83				2.09	0.26	3.43				
	Accuracy		4.10	-17.03	5.31	-1.20	-0.90	30.71	-26.49	6.54	-10.29	-4.68				6.00	0.44	5.42				

RSD calculated as: (standard deviation/mean)*100

accuracy Calculated as: (Accepted value-measured value)/accepted value*100

APPENDIX 37 Precision and accuracy HYDE

	Hyde																								
	Normalised	Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
CorningB	Average	0.12	0.91	16.93	1.04	8.48		0.02	0.10	0.02	0.36	0.25	0.05	2.64	0.20	4.35	62.75	0.82	0.49	-0.10	0.00	0.47
	Stdev	0.01	0.01	0.20	0.05	0.04		0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.04	0.17	0.03	0.01	0.01	0.00	0.01
	B Known		1.00	17.00	1.03	8.56		0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.50	0.46	0.04	0.61
	RSD Precision	8.19	1.37	1.17	5.07	0.46		25.80	2.87	2.65	0.74	0.86	1.73	0.86	1.09	0.81	0.28	4.01	2.78	-9.56	178.78	1.45
	Accuracy		8.76	0.40	-0.60	0.98		82.14	-17.83	8.93	-6.24	-1.21	0.27	0.57	-5.87	0.15	-1.99	0.34	2.70	121.42	96.55	22.86
CorningD	Average	0.01	11.33	1.20	3.95	15.09		0.24	0.38	0.01	0.58	0.62	0.02	0.39	0.10	5.31	56.12	3.94	0.00	0.35	0.05	0.27
	StdeV	0.01	0.05	0.17	0.11	0.08		0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.15	0.06	0.00	0.08	0.01	0.00
	Known		11.3	1.2	3.94	14.8		0.291	0.38	0.0125	0.52	0.55	0.023	0.38	0.1	5.3	55.24	3.93	0.23	0.97	0.1	0.241
	RSD Precision	80.64	0.43	14.40	2.79	0.52		4.22	1.36	7.31	0.61	0.74	3.46	0.86	1.29	1.00	0.27	1.40		22.89	25.42	1.22
	Accuracy		-0.28	-0.22	-0.22	-1.98		17.46	1.01	12.33	-10.68	-12.32	10.88	-2.34	-2.02	-0.22	-1.59	-0.22	100.00	63.79	51.62	-11.49
	RSD	calculated as: (standard deviation/mean)*100																				
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																				

APPENDIX 38 Precision and accuracy LOUTH PARK

	Louth Park Normalised	Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Corning B	Average	0	0.91	17.17	1.04	8.86	0.02	0.03	0.11	0.03	0.4	0.28	0.05	2.7	0.23	4.41	61.63	0.84	0.2	0.46	0	0.54
	Stdev	0	0.007	0.264	0.062	0.091	0.001	0.008	0.004	0.001	0.006	0.004	0.001	0.084	0.004	0.073	0.183	0.028	0.03	0.067	0.003	0.013
	Known		1	17	1.03	8.56	0.02	0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.5	0.46	0.04	0.61
	RSD Precision		0.72	1.53	5.98	1.02	4.6	27.19	3.36	4.2	1.4	1.5	1.92	3.11	1.95	1.66	0.3	3.39	15.26	14.64	412.31	2.48
	Accuracy		8.53	-1.01	-1.06	-3.46	-7.11	74.12	-23.82	-7.51	-18.24	-10.1	-9.86	-1.36	-18.49	-1.06	-0.18	-2.3	60.27	0.43	98.35	11.29
Corning D	Average	0.11	11.29	1.19	3.93	15.51	0.06	0.26	0.37	0.01	0.58	0.64	0.02	0.31	0.1	5.29	54.95	3.93	0.09	0.96	0.04	0.29
	St Dev	0.007	0.094	0.2	0.08	0.098	0.001	0.022	0.008	0.001	0.006	0.008	0.001	0.004	0.002	0.047	0.194	0.041	0.014	0.078	0.013	0.006
	Known		11.3	1.2	3.94	14.8	0.057	0.291	0.38	0.0125	0.52	0.55	0.023	0.38	0.1	5.3	55.24	3.93	0.23	0.97	0.1	0.241
	RSD Precision	6.84	0.84	16.86	2.03	0.63	2.16	8.41	2.27	9.62	1.1	1.25	5.34	1.33	1.68	0.88	0.35	1.04	15.4	8.08	31.39	1.92
	Accuracy	#DIV/0!	0.13	0.94	0.2	-4.8	-13.24	9.21	1.73	5.92	-12.45	-15.6	5.84	17.6	-4.77	0.19	0.53	-0.06	61.31	0.94	57.35	-19.78
	RSD	calculated as: (standard deviation/mean)*100																				
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																				

APPENDIX 39 Precision and accuracy RIEVAULX

	Rievaulx																												
	Spectrum	Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO							
CL 330	CL330 ave 01	0.00	1.40	8.62	6.41	22.68	0.02	0.00	0.00	0.20	0.33	0.00	0.00	0.08	0.00	0.11	4.36	54.99	0.42	0.00	0.35	0.00	0.00						
	Stdev	0.00	0.02	0.31	0.08	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.14	0.00	0.00	0.00	0.00	0.00						
	Known		1.50	9.50	6.60	21.90	0.02			0.20	0.30			0.09		0.10	4.30	55.40											
	RSD Precision		1.18	3.57	1.18	0.93	0.67			0.95	0.92			2.44		1.00	0.60	0.26											
	Accuracy		6.39	9.27	2.83	-3.58	-17.99			2.14	-11.26			5.92		-13.44	-1.34	0.73											
CorningA	Corn A Av	0.04	2.68	14.22	2.69	4.99	0.11	0.41	0.73	0.00	1.15	1.08	0.18	1.16	0.05	1.04	67.45	0.42	0.15	1.31	0.06	0.07							
	Stdev	0.01	0.02	0.43	0.02	0.05	0.00	0.01	0.01	0.00	0.02	0.01	0.00	0.02	0.00	0.02	0.36	0.00	0.02	0.11	0.01	0.00							
	Known		2.87	14.30	2.66	5.03	0.10	0.56	0.79	0.00	1.09	1.00	0.17	1.17	0.04	1.00	66.76	0.13	0.10	1.75	0.19	0.12							
	RSD Precision		0.67	3.01	0.85	0.91	2.45	1.92	1.97		1.36	0.86	0.68	1.36	2.14	2.24	0.53	0.08	11.15	8.33	11.21	1.06							
	Accuracy		6.72	0.56	-1.24	0.85	-5.55	26.83	7.26		-5.48	-8.27	-7.49	1.26	-7.72	-3.50	-1.04	-225.84	-46.84	25.36	70.87	42.62							
Corning B	Corning B Av	0.10	0.91	17.53	0.92	8.62	0.02	0.02	0.11	0.02	0.36	0.25	0.05	0.05	2.70	0.20	4.38	61.38	0.86	0.42	0.50	0.08	0.47						
	Stdev	0.00	0.01	0.33	0.03	0.04	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.08	0.13	0.04	0.02	0.08	0.05	0.02						
	Known		1.00	17.00	1.03	8.56	0.02	0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.50	0.46	0.04	0.61							
	RSD Precision		0.73	1.90	3.37	0.47	5.11	28.41	2.19	13.15	0.38	0.90	4.78	0.56	0.61	1.90	0.21	4.09	5.24	16.78	58.70	3.47							
	Accuracy		9.12	-3.14	10.67	-0.73	8.87	81.89	-23.72	29.86	-6.36	-1.21	0.30	-1.32	-4.79	-0.36	0.22	-5.02	15.44	-9.57	-105.19	23.40							
Corning C	Corning C Av	0.00	2.39	1.40	2.93	4.80	0.29	11.29	1.11	0.06	0.32	0.00	0.18	1.09	0.02	0.86	35.60	0.42	0.00	0.38	0.00	36.87							
	Stdev	0.00	0.03	0.53	0.42	0.03	0.01	0.19	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.15	0.08	0.00	0.00	0.06	0.00	0.82							
	Known		2.84	1.07	2.76	5.07	0.29	11.40	0.79	0.01	0.34	0.00	0.18	1.13	0.05	0.87	35.88	0.14	0.10	0.03	0.19	36.70							
	RSD Precision		1.23	38.08	14.48	0.59	4.04	1.72	2.03	0.70	1.63		0.86	1.13	30.57	17.31	0.23	0.03	#DIV/0!	15.12	#DIV/0!	2.21							
	Accuracy		15.94	-30.43	-6.15	5.40	0.03	1.00	-39.92	-1020.51	7.24		-1.62	3.48	52.21	1.27	0.78	-196.82	100.00	-1178.14	100.00	-0.46							
Corning D	Corn D Av	0.09	11.32	1.28	3.98	15.49	0.06	0.23	0.41	0.01	0.57	0.62	0.02	0.38	0.10	5.15	54.61	3.89	0.08	1.36	0.03	0.28							
	Stdev	0.01	0.01	0.16	0.04	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.13	0.07	0.01	0.09	0.02	0.00							
	Known	11.30		1.20	3.94	14.80	0.06	0.29	0.38	0.01	0.52	0.55	0.02	0.38	0.10	5.30	55.24	3.93	0.23	0.97	0.10	0.24							
	RSD Precision		0.06	12.80	0.89	0.36	1.29	5.61	1.02	3.89	0.05	0.33	2.23	0.79	1.14	1.06	0.24	1.78	12.35	6.85	91.16	0.71							
	Accuracy		-0.17	-6.31	-1.08	-4.68	-11.28	22.48	-7.01	13.93	-9.58	-12.67	11.09	0.70	-2.47	2.86	1.14	1.13	65.52	-40.39	73.21	-14.18							
EH Tender	EH2 Av	0.08	5.66	0.84	2.88	20.20	0.11	0.16	0.34	0.04	0.97	1.44	0.02	0.01	0.02	1.95	62.73	1.80	0.34	0.35	0.00	0.03							
	Stdev	0.04	0.10	0.09	0.07	0.28	0.00	0.01	0.02	0.00	0.03	0.03	0.00	0.00	0.00	0.02	0.41	0.03	0.05	0.00	0.00	0.00							
	Known		5.8	0.86	3.06	19.69	0.11	0.23	0.27	0.048	0.87	1.36	0	0		2.05	63.7	1.88											
	RSD Precision		1.72	10.89	2.60	1.37	1.93	6.47	6.08	2.38	2.80	1.90			6.41	1.27	0.65	1.61	14.09	0.02		6.75							
	Accuracy		2.42	1.87	5.79	-2.57	-1.68	28.33	-27.42	6.44	-11.60	-5.92				5.11	1.52	4.43											
	RSD	calculated as: (standard deviation/mean)*100																											
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																											

APPENDIX 40 Precision and accuracy WHITBY

	Whitby																									
	Normalised	Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO				
CL 330	Average	0.01	1.37	10.38	6.32	22.01	0.02	0	0	0	0.19	0.32	0	0.08	0	0.11	4.32	54	0.5	0	0.36	0	0				
	Stdev	0.01	0.02	0.31	0.1	0.17	0	0	0	0	0	0	0	0	0	0	0.04	0.2	0	0	0	0	0				
	Known	0	1.5	9.5	6.6	21.9	0.02	0	0	0	0.2	0.3	0	0.09	0	0.1	4.3	55.4	0	0	0	0	0				
	RSD Precision		1.32	2.98	1.61	0.79	1.41				1.57	1.33		1.28		1.26	0.85	0.37								
	Accuracy		8.4	-9.26	4.26	-0.5	-11.26				4.11	-7.86		8.25		-8.35	-0.44	2.53								
Corning B	Average	0.11	0.94	17.41	0.95	8.64	0.02	0.01	0.11	0.02	0.36	0.26	0.05	2.69	0.2	4.3	61.6	0.85	0.44	0.46	0.05	0.45				
	Stdev	0.01	0.04	0.36	0.06	0.07	0	0	0	0	0.01	0	0	0.04	0	0.07	0.18	0.04	0.02	0.03	0.03	0.01				
	Known	0	1	17	1.03	8.56	0.02	0.12	0.09	0.03	0.34	0.25	0.05	2.66	0.19	4.36	61.52	0.82	0.5	0.46	0.04	0.61				
	RSD Precision		3.96	2.07	6.26	0.81	7.57	23.83	4.56	13.17	1.48	1.56	1.9	1.66	1.34	1.58	0.3	5.04	5.38	6.91	72.24	2.75				
	Accuracy		5.96	-2.43	8.12	-0.94	12.59	87.54	-22.58	33.7	-6.83	-2.25	1.4	-0.98	-3.58	1.26	-0.12	-3.74	12.74	-1.02	-13.49	25.47				
Corning D	Average	0.09	11.27	1.44	4.03	15.48	0.06	0.23	0.38	0.01	0.57	0.63	0.02	0.38	0.1	5.2	54.81	3.9	0.06	0.96	0.04	0.28				
	Stdev	0.01	0.07	0.16	0.08	0.11	0	0.01	0	0	0.01	0.01	0	0	0	0.05	0.06	0.06	0.01	0.14	0.04	0				
	Known	0	11.3	1.2	3.94	14.8	0.06	0.29	0.38	0.01	0.52	0.55	0.02	0.38	0.1	5.3	55.24	3.93	0.23	0.97	0.1	0.24				
	RSD Precision		0.61	10.79	1.88	0.7	1.85	4.35	1.05	8.34	1.01	1.08	4.76	0.98	1.02	0.88	0.1	1.51	21.78	15.02	95.95	1.61				
	Accuracy		0.25	-20.14	-2.21	-4.58	-12.33	21.05	-0.87	15.31	-9.4	-13.88	7.74	-0.44	-2.13	1.91	0.78	0.87	71.78	1.14	56	-16.17				
HE Tender 02	Average	0.07	5.52	1.17	3.06	19.72	0.11	0.15	0.31	0.04	0.95	1.41	0.01	0.01	0.02	2.01	62.93	1.81	0.29	0.36	0	0.03				
	Stdev	0.01	0.01	0.12	0.08	0.08	0	0.01	0.01	0	0.01	0.01	0	0	0	0.03	0.13	0.06	0.02	0	0	0				
	Known	0	5.8	0.86	3.06	19.69	0.11	0.23	0.27	0.05	0.87	1.36	0	0	0	2.05	63.7	1.88	0	0	0	0				
	RSD Precision		0.25	10.62	2.65	0.41	0.82	7.41	2.8	2.27	0.89	0.62				1.52	0.21	3.51								
	Accuracy		4.8	-35.84	0.02	-0.17	0.6	34.19	-16.26	7.96	-8.77	-3.61				2.18	1.21	3.57								
	RSD	calculated as: (standard deviation/mean)*100																								
	accuracy	Calculated as: (Accepted value-measured value)/accepted value*100																								

APPENDIX 41 Precision and accuracy CORNING A

Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Bardney	RSD Precision		0.3	0.7	3.8	0.7	4.4	1.7	0.6		0.1	0.2	0.9	1.7	1.1	1.5	0.2	0.1	4.0	13.1	24.3	1.3
Bordesley	RSD Precision		0.7	2.5	3.6	0.7	6.8	2.2	0.5		0.8	0.6	1.6	1.7	1.3	1.6	0.5	0.1	3.1	24.1	102.4	3.3
Rievaulx	RSD Precision		0.7	3.0	0.8	0.9	2.4	1.9	2.0		1.4	0.9	0.7	1.4	2.1	2.2	0.5	0.1	11.1	8.3	11.2	1.1
A	**P ave**		**0.6**	**2.0**	**2.7**	**0.8**	**4.5**	**2.0**	**1.0**		**0.8**	**0.5**	**1.1**	**1.6**	**1.5**	**1.8**	**0.4**	**0.1**	**6.1**	**15.2**	**46.0**	**1.9**
Bardney	Accuracy		7.9	0.3	-2.8	1.5	-8.2	29.7	6.5		-5.9	-8.7	-7.4	1.2	-8.6	-1.7	-0.5	-281.2	-45.7	11.2	55.6	41.7
Bordesley	Accuracy		6.7	-1.0	-1.6	0.4	-8.5	27.6	2.1		-8.2	-10.9	-10.4	0.7	-11.2	-1.5	-1.7	-277.2	-50.4	72.2	76.2	40.4
Rievaulx	Accuracy		6.7	0.6	-1.2	0.9	-5.6	26.8	7.3		-5.5	-8.3	-7.5	1.3	-7.7	-3.5	-1.0	-225.8	-46.8	25.4	70.9	42.6
A	**A ave**		**7.1**	**0.0**	**-1.9**	**0.9**	**-7.4**	**28.0**	**5.3**		**-6.5**	**-9.3**	**-8.4**	**1.0**	**-9.2**	**-2.2**	**-1.1**	**-261.4**	**-47.7**	**36.2**	**67.6**	**41.6**

APPENDIX 42 Precision and accuracy CORNING B

	Normalised	Cl	K2O	Na2O	MgO	CaO	Sr	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Alcester	Precision		2.12	2.37	8.53	1.03		23.17	1.24	9.89	1.18	2.08	0.70	1.31	0.98	0.76	0.53	3.21	8.75	45.09		2.18
Bardney	Precision		4.85	1.91	12.48	1.06	11.41	42.03	4.11	25.31	1.24	1.59	1.94	1.52	1.54	1.98	0.41	7.10	5.76	24.21	74.15	5.62
Bordesley	Precision		4.01	1.62	9.33	0.95	9.73	40.26	3.70	20.29	1.62	1.62	2.44	2.48	2.61	1.77	0.39	5.31	4.94	48.47	79.72	6.01
Hyde	Precision		1.37	1.17	5.07	0.46		25.80	2.87	2.65	0.74	0.86	1.73	0.86	1.09	0.81	0.28	4.01	2.78	-9.56	178.78	1.45
Louth Park	Precision		0.72	1.53	5.98	1.02	4.60	27.19	3.36	4.20	1.40	1.50	1.92	3.11	1.95	1.66	0.30	3.39	15.26	14.64	412.31	2.48
Rievaulx	Precision		0.73	1.90	3.37	0.47	5.11	28.41	2.19	13.15	0.38	0.90	4.78	0.56	0.61	1.90	0.21	4.09	5.24	16.78	58.70	3.47
Whitby	Precision		3.96	2.07	6.26	0.81	7.57	23.83	4.56	13.17	1.48	1.56	1.90	1.66	1.34	1.58	0.30	5.04	5.38	6.91	72.24	2.75
B	**P ave**		**2.54**	**1.79**	**7.29**	**0.83**	**7.68**	**30.10**	**3.15**	**12.67**	**1.15**	**1.44**	**2.20**	**1.64**	**1.44**	**1.50**	**0.35**	**4.59**	**6.87**	**20.93**	**145.98**	**3.42**
Alcester	Accuracy		7.92	-0.17	-0.18	-1.50		81.98	-17.62	21.14	-8.37	-2.91	-3.16	-0.19	-6.82	-0.17	-0.89	-0.17	-4.08	67.96	100.00	21.88
Bardney	Accuracy		5.29	-3.45	17.37	-1.83	12.70	84.86	-29.35	33.99	-8.16	-3.36	-0.54	-1.32	-5.21	1.11	0.08	-3.90	12.58	15.07	-3.83	24.58
Bordesley	Accuracy		6.20	-2.05	14.63	-2.56	8.54	85.07	-34.01	27.48	-9.27	-4.12	-1.53	-0.78	-6.93	0.38	-0.63	-1.31	12.02	82.36	3.93	21.96
Hyde	Accuracy		8.76	0.40	-0.60	0.98		82.14	-17.83	8.93	-6.24	-1.21	0.27	0.57	-5.87	0.15	-1.99	0.34	2.70	121.42	96.55	22.86
Louth Park	Accuracy		8.53	-1.01	-1.06	-3.46	-7.11	74.12	-23.82	-7.51	-18.24	-10.10	-9.86	-1.36	-18.49	-1.06	-0.18	-2.30	60.27	0.43	98.35	11.29
Rievaulx	Accuracy		9.12	-3.14	10.67	-0.73	8.87	81.89	-23.72	29.86	-6.36	-1.21	0.30	-1.32	-4.79	-0.36	0.22	-5.02	15.44	-9.57	-105.19	23.40
Whitby	Accuracy		5.96	-2.43	8.12	-0.94	12.59	87.54	-22.58	33.70	-6.83	-2.25	1.40	-0.98	-3.58	1.26	-0.12	-3.74	12.74	-1.02	-13.49	25.47
B	**A ave**		**7.40**	**-1.69**	**6.99**	**-1.43**	**7.12**	**82.51**	**-24.13**	**21.08**	**-9.07**	**-3.59**	**-1.88**	**-0.77**	**-7.38**	**0.19**	**-0.50**	**-2.30**	**15.95**	**39.52**	**25.19**	**21.64**

APPENDIX 43 Precision and accuracy CORNING C

Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Bardney	RSD Precision		1.07	20.99	4.31	0.82	3.64	0.49	1.35	11.62	0.29			1.76	0.31	2.78	2.42	0.35	0.09		27.57		0.57
Bordesley	RSD Precision		1.28	22.22	3.02	0.91	3.70	0.63	7.51	10.40	0.69			1.58	0.31	2.39	2.96	1.94	0.06		244.95	120.93	1.57
Rievaulx	RSD Precision		1.23	38.08	14.48	0.59	4.04	1.72	2.03	0.70	1.63			0.86	1.13	30.57	17.31	0.23	0.03		15.12		2.21
C	**P ave**		**1.19**	**27.09**	**7.27**	**0.77**	**3.79**	**0.95**	**3.63**	**7.64**	**0.87**			**1.40**	**0.58**	**11.92**	**7.56**	**0.84**	**0.06**		**95.88**	**120.93**	**1.45**
Bardney	Accuracy		16.99	-23.53	-10.27	6.24	-2.07	2.11	-46.35	-1176.03	6.99			-1.27	3.35	44.37	-0.82	1.45	-247.91		-749.18	100.00	-1.40
Bordesley	Accuracy		17.66	-18.33	-6.40	6.32	-4.83	1.56	-42.22	-1230.06	6.54			-1.33	5.07	43.34	2.07	2.78	-240.21		72.31	-38.49	-3.17
Rievaulx	Accuracy		15.94	-30.43	-6.15	5.40	0.03	1.00	-39.92	-1020.51	7.24			-1.62	3.48	52.21	1.27	0.78	-196.82		-1178.14	100.00	-0.46
C	**A ave**		**16.86**	**-24.10**	**-7.61**	**5.98**	**-2.29**	**1.56**	**-42.83**	**-1142.20**	**6.92**			**-1.41**	**3.97**	**46.64**	**0.84**	**1.67**	**-228.32**		**-618.34**	**53.84**	**-1.67**

APPENDIX 44 Precision and accuracy CORNING D

	Normalised	Cl	K2O	Na2O	MgO	CaO	Sr	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Alcester	RSD Precision			9.46	2.32	0.37		3.21	0.62	4.32	0.44	0.41	3.31	0.70	1.56	1.86	0.13	1.05	17.36	3.49	35.64	2.08
Bardney	RSD Precision			14.94	3.71	1.00	3.66	9.11	2.51	13.26	1.71	1.49	8.39	1.99	2.46	2.20	0.48	2.93	32.05	31.19	81.11	2.80
Bordesley	RSD Precision			-4.74	1.92	-6.66	-15.73	19.44	-12.56	14.76	-12.77	-16.46	8.15	-0.30	-5.39	1.27	0.32	1.22	72.11	49.88	51.22	-20.23
Hyde	RSD Precision			14.40	2.79	0.52		4.22	1.36	7.31	0.61	0.74	3.46	0.86	1.29	1.00	0.27	1.40		22.89	25.42	1.22
Louth Park	RSD Precision			16.86	2.03	0.63	2.16	8.41	2.27	9.62	1.10	1.25	5.34	1.33	1.68	0.88	0.35	1.04	15.40	8.08	31.39	1.92
Rievaulx	RSD Precision			12.80	0.89	0.36	1.29	5.61	1.02	3.89	0.05	0.33	2.23	0.79	1.14	1.06	0.24	1.78	12.35	6.85	91.16	0.71
Whitby	RSD Precision			10.79	1.88	0.70	1.85	4.35	1.05	8.34	1.01	1.08	4.76	0.98	1.02	0.88	0.10	1.51	21.78	15.02	95.95	1.61
D	**P ave**		**0.30**	**10.64**	**2.22**	**-0.44**	**-1.35**	**7.76**	**-0.53**	**8.79**	**-1.12**	**-1.59**	**5.09**	**0.91**	**0.54**	**1.31**	**0.27**	**1.56**	**28.51**	**19.63**	**58.84**	**-1.41**
Alcester	Accuracy		0.06	0.13	0.13	-5.39		16.05	1.26	5.86	-11.22	-15.17	6.76	0.83	-4.50	0.13	0.94	0.13	54.86	-3.93	-0.37	-19.68
Bardney	Accuracy		1.09	-4.51	3.84	-3.66	-11.63	18.87	-6.28	13.27	-12.38	-14.51	10.37	-5.64	-4.19	0.01	0.87	7.65	100.00	-99.22	66.42	-14.99
Bordesley	Accuracy		-0.97	-4.74	1.92	-6.66	-15.73	19.44	-12.56	14.76	-12.77	-16.46	8.15	-0.30	-5.39	1.27	0.32	1.22	72.11	49.88	51.22	-20.23
Hyde	Accuracy		-0.28	-0.22	-0.22	-1.98		17.46	1.01	12.33	-10.68	-12.32	10.88	-2.34	-2.02	-0.22	-1.59	-0.22	100.00	63.79	51.62	-11.49
Louth Park	Accuracy		0.13	0.94	0.20	-4.80	-13.24	9.21	1.73	5.92	-12.45	-15.60	5.84	17.60	-4.77	0.19	0.53	-0.06	61.31	0.94	57.35	-19.78
Rievaulx	Accuracy		-0.17	-6.31	-1.08	-4.68	-11.28	22.48	-7.01	13.93	-9.58	-12.67	11.09	0.70	-2.47	2.86	1.14	1.13	65.52	-40.39	73.21	-14.18
Whitby	Accuracy		0.25	-20.14	-2.21	-4.58	-12.33	21.05	-0.87	15.31	-9.40	-13.88	7.74	-0.44	-2.13	1.91	0.78	0.87	71.78	1.14	56.00	-16.17
D	**A ave**		**0.02**	**-4.98**	**0.37**	**-4.54**	**-12.84**	**17.80**	**-3.25**	**11.63**	**-11.21**	**-14.37**	**8.69**	**1.49**	**-3.64**	**0.88**	**0.43**	**1.53**	**75.08**	**-3.97**	**50.78**	**-16.65**

APPENDIX 45 Precision and accuracy CL330

Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Bardney	RSD Precision		2.01	11.33	9.37	3.11	6.52			5.43	2.80		2.96		2.24	5.16	1.96					
Bordesley	RSD Precision		1.31	2.96	1.68	0.97	2.67			2.90	1.73		2.37		2.13	1.18	0.43					
Rievaulx	RSD Precision		1.18	3.57	1.18	0.93	0.67			0.95	0.92		2.44		1.00	0.60	0.26					
Whitby	RSD Precision		1.32	2.98	1.61	0.79	1.41			1.57	1.33		1.28		1.26	0.85	0.37					
CL	**P ave**		**1.45**	**5.21**	**3.46**	**1.45**	**2.82**			**2.71**	**1.70**		**2.26**		**1.66**	**1.95**	**0.76**					
Bardney	Accuracy		6.29	10.26	3.39	-4.29	-13.78			-2.84	-12.74		3.69		-12.68	-1.26	0.69					
Bordesley	Accuracy		6.44	7.31	4.46	-3.44	-14.99			0.04	-11.45		4.79		-12.54	-3.03	0.44					
Rievaulx	Accuracy		6.39	9.27	2.83	-3.58	-17.99			2.14	-11.26		5.92		-13.44	-1.34	0.73					
Whitby	Accuracy		8.4	-9.26	4.26	-0.5	-11.26			4.11	-7.86		8.25		-8.35	-0.44	2.53					
CL	**A ave**		**6.88**	**4.39**	**3.73**	**-2.95**	**-14.50**			**0.86**	**-10.83**		**5.66**		**-11.75**	**-1.52**	**1.10**					

APPENDIX 46 Precision and accuracy EH T2

Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
Bardney	RSD Precision		0.64	20.34	2.14	0.57	2.28	10.30	3.35	2.01	0.83	0.88					0.96	0.29	3.59			
Bordesley	RSD Precision		17.69	3.91	0.59	1.79	9.87	3.18	2.35	1.06	0.83						0.26	3.43	3.43			
Rievaulx	RSD Precision		1.72	10.89	2.60	1.37	1.93	6.47	6.08	2.38	2.80	1.90					1.27	0.65	1.61	14.09	0.02		6.75
Whitby	RSD Precision		0.25	10.62	2.65	0.41	0.82	7.41	2.80	2.27	0.89	0.62					1.52	0.21	3.51				
EH T02	**P ave**		**5.08**	**11.44**	**1.99**	**1.03**	**3.73**	**6.84**	**3.64**	**1.93**	**1.34**	**1.13**					**1.00**	**1.14**	**3.04**				
Bardney	Accuracy		3.39	-16.81	5.57	-1.02	-1.17	28.05	-20.62	6.23	-10.50	-4.49					3.96	0.88	3.40				
Bordesley	Accuracy		4.10	-17.03	5.31	-1.20	-0.90	30.71	-26.49	6.54	-10.29	-4.68					6.00	0.44	5.42				
Rievaulx	Accuracy		2.42	1.87	5.79	-2.57	-1.68	28.33	-27.42	6.44	-11.60	-5.92					5.11	1.52	4.43				
Whitby	Accuracy		4.80	-35.84	0.02	-0.17	0.60	34.19	-16.26	7.96	-8.77	-3.61					2.18	1.21	3.57				
EH T02	**A ave**		**3.68**	**-16.95**	**4.17**	**-1.24**	**-0.79**	**30.32**	**-22.70**	**6.79**	**-10.29**	**-4.68**					**4.31**	**1.01**	**4.20**				

APPENDIX 47 Precision and accuracy AVERAGE ALL STANDARDS

Normalised		Cl	K2O	Na2O	MgO	CaO	SrO	BaO	TiO2	ZrO2	Fe2O3	MnO	CoO	CuO	ZnO	Al2O3	SiO2	P2O5	SO3	Sb2O5	SnO2	PbO
A	P ave		0.56	2.04	2.73	0.77	4.53	1.96	1.04		0.77	0.54	1.08	1.59	1.52	1.78	0.38	0.09	6.09	15.18	45.98	1.86
B	P ave		2.54	1.79	7.29	0.83	7.68	30.10	3.15	12.67	1.15	1.44	2.20	1.64	1.44	1.50	0.35	4.59	6.87	20.93	145.98	3.42
C	P ave		1.19	27.09	7.27	0.77	3.79	0.95	3.63	7.64	0.87		1.40	0.58	11.92	7.56	0.84	0.06		95.88	120.93	1.45
D	P ave	32.48	0.30	10.64	2.22	-0.44	-1.35	7.76	-0.53	8.79	-1.12	-1.59	5.09	0.91	0.54	1.31	0.27	1.56	28.51	19.63	58.84	-1.41
CL	P ave		1.45	5.21	3.46	1.45	2.82			2.71	1.70		2.26		1.66	1.95	0.76					
EHT02	P ave		5.08	11.44	1.99	1.03	3.73	6.84	3.64	1.93	1.34	1.13				1.00	1.14	3.04				
Ave			**1.85**	**9.70**	**4.16**	**0.74**	**3.53**	**9.52**	**2.19**	**6.75**	**0.78**	**0.38**	**2.41**	**1.18**	**3.41**	**2.52**	**0.62**	**1.87**	**13.82**	**37.91**	**92.93**	**1.33**
A	A ave		7.12	-0.04	-1.88	0.94	-7.41	28.03	5.28		-6.52	-9.30	-8.44	1.05	-9.17	-2.22	-1.08	-261.40	-47.66	36.24	67.56	41.57
B	A ave		7.40	-1.69	6.99	-1.43	7.12	82.51	-24.13	21.08	-9.07	-3.59	-1.88	-0.77	-7.38	0.19	-0.50	-2.30	15.95	39.52	25.19	21.64
C	A ave		16.86	-24.10	-7.61	5.98	-2.29	1.56	-42.83	-1142.20	6.92		-1.41	3.97	46.64	0.84	1.67	-228.32		-618.34	53.84	-1.67
D	A ave		0.02	-4.98	0.37	-4.54	-12.84	17.80	-3.25	11.63	-11.21	-14.37	8.69	1.49	-3.64	0.88	0.43	1.53	75.08	-3.97	50.78	-16.65
CL	A ave		6.88	4.39	3.73	-2.95	-14.50			0.86	-10.83		5.66		-11.75	-1.52	1.10					
EHT02	A ave		3.68	-16.95	4.17	-1.24	-0.79	30.32	-22.70	6.79	-10.29	-4.68				4.31	1.01	4.20				
Ave			**6.99**	**-7.23**	**0.96**	**-0.54**	**-5.12**	**32.04**	**-17.52**	**-220.37**	**-6.83**	**-7.99**	**0.53**	**1.43**	**2.94**	**0.41**	**0.44**	**-97.26**	**14.46**	**-136.64**	**49.34**	**11.22**

APPENDIX 48a Standards analyses dates

Date of session (start)	Site	Standards	No. analyses (X3 pts) and time period when standards were run	
29/04/2022	Alcester	Corning B	1	end of session
		Corning D	1	end of session
16-19/5/22	Hyde	Corning B	8	start, end
		Corning D	8	start, end
18-20/10/22	Louth	Corning B	6	start, end
		Corning D	6	start, end
28/2-2/3/23	Bordesley	Corning A	1	start
		Corning B	7	start, middle, end
		Corning C	1	start
		Corning D	7	start, middle, end
		CL330	1	start
3-7/3/23	Bardney	Corning A	1	start
		Corning B	6	start, middle, end
		Corning C	1	start
		Corning D	6	start, middle, end
		CL330	2	start, middle
		EH Tender 02	2	start, middle
7-9/3/23	Whitby	Corning B	3	middle
		Corning D	3	middle
		CL330	3	middle
		EH Tender 02	3	middle
11-14/7/23	Rievaulx	Corning A	1	start
		Corning B	1	start
		Corning C	1	start
		Corning D	8	start, middle, end
		CL330	1	start
		EH Tender 02	1	start

APPENDIX 48b Limit of detection

Uncorrected	LOD SDRegression
Na2O	0.88
MgO	0.26
Al2O3	0.65
P2O5	0.59
K2O	0.42
TiO2	0.12
MnO2	0.10
Fe2O3	0.08
CoO	0.01
CuO	0.11
Rb2O	0.05
SrO	0.01
ZrO2	0.02
Sb2O5	0.91
PbO	0.27
ZnO	0.01
BaO	0.15
SnO2	0.22
SiO2	1.78
CaO	4.37
SO3	0.26
Cl	

Stylistic dating	Sample number	Decoration	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info
First third C13	ALC 5	SLG	Lincoln Cathedral	1220-35	10037	Dean's Eye								
	ALC 6	SLG	York Minster	1220-55	Vidimus 143, fig 5	Stumpy berry stem	Stanton Harcourt, Oxon	1250-80	3312	Marks=1260-75				
	ALC 12B	SLG	W Horseley, Surrey	1210-25	Baker:20		Waterperry, Oxon	m-l.C13	9948					Curling stem on xh b/g
	ALC 14	SLG	Lincoln Cathedral	e.C13	007434, 024940	C19 drawing								3 lobes on XH b/g
	ALC 18	SLG	Lincoln Cathedral	e.C13	7434, 24940									
	ALC 20	SLG	Lincoln Cathedral	e.C13	7434, 24940									
	ALC 88	SLG	W Horsley	1210-25	Marks:139		Salisbury Cathedral	e-mid C13	9954					
	ALC 65A red streaky	Grisaille boss	Lincoln Cathedral	e. C13	217	corner quarry	Bayham Abbey	e. C13	Kerr, p. 606 (107)		Westwell	e. C13	7386	
	ALC 44 amber	Lombardic lettering	Canterbury Cathedral	e. C13	Michael, p. 131, 133, 139									
	ALC 46 amber	Lombardic lettering	Canterbury Cathedral	e. C13	Michael, p. 131, 133, 139									
	ALC 47 amber	Lombardic lettering	Canterbury Cathedral	e. C13	Michael, p. 41, 131, 133,	Ezekias S. XXVIII, c6	Westwell	eC13	7386					
	ALC 73C amber	serpentine border	Canterbury Cathedral	e. C13	Michael, p. 140	aspects of	Canterbury Cathedral	l. C12	Michael, p. 101	Aspects of Tree of Jesse				
	ALC 0742	Plain												
	ALC 0748	Plain												
	ALC 0897	Plain												
C13/14	ALC 93	Naturalistic grissaille	YM Chapter Hs	1280-90	21247		Eaton Bishop	1330-35	2909					
2nd Q C14	ALC 74	Demon head	Hadzor Ch	c.1340	no no.Ely SG museum									
	ALC 76M	Rinceau	Tewksbury Abbey	m.C14	1758									
	ALC 79M	Beast/claw	Stanford on A	1330-50	20875	similar to ALC 80								
	ALC 86M	Vegetal/ foliate	Lowick, N'hants	1310-40	1363									
	ALC 90	Figurative	Hadzor Ch	c.1340	no no.Ely SG museum									
	ALC 91M	Vegetal/ foliate	Madley, Herts	c.1350	22911		Wells Cathedral	1335-45	8030					
	ALC 49 blue	Diaper	Hadzor Ch	c.1340	no no.Ely SG museum		Tewkesbury Abbey	m.C14	1758					
	ALC 53 green	Quatrefoil	Tewkesbury Abbey	e.-m.C14	1758									
	ALC 57B green	Vegetal	Madley, Herts	c.1350	22911		Wells Cathedral	1335-45	8030		Lowick, N'hants	1310-40	1363	
	ALC 60 red pot	Rinceau	Tewkesbury Abbey	m.C14	1758		YM west window	1339	3743, 3729		Stanford on A	1330-50	20875	
	ALC 61 x1 flash	Strapwork	Tewkesbury Abbey	m.C14	1758									
	ALC 68 amber	Foliate border	Eaton Bishop	1317-21	Baker, pl. 42	Graves makes comparison	Sempringham	e-m. C14	Graves, fig. 180 (250)	Internal veins				
	ALC 75 murrey	Figurative	Waterperry, Oxon	e.C14-mid	9982		Lowick, N'hants	1310-40	1360		Eaton Bishop	1330-35	20120	
	ALC 41 SS	Branching foliate	Eaton Bishop	1330-35	14742		Tewkesbury abbey	1338-40	1757	border				
	ALC 41A SS	Naturalistic grisaille	Eaton Bishop	1330-35	14730, 20130	similar	Waterperry	e-m. C14	9982					
	ALC 42 SS	Naturalistic grisaille	Eaton Bishop	1330-35	14730, 20130	similar	Waterperry	e-m. C14	9982					
	ALC 42B SS	Demon head	Stanforn-on-Avon	1330-50	1603		Hadzor Ch	c.1340	Vidimus 108, fig 2					
	ALC 80 SS	Rinceau	Stanford on A	1330-50	20875	similar to ALC 79								
	ALC 92 SS	Naturalistic grisaille	Eaton Bishop	1330-35	14730, 20130	similar	Waterperry	e-m. C14	9982					
	ALC 0898	Plain												
C15/16	ALC 43	Gothic lettering	Margaretting, Essex	1460	5018, 25255		East Harling	L.C15	15867					

Bibliography

Kerr, 1983

Michael. 2004

York Minster Stain Glass Navigator

Baker, 1978

Marks, 1993

Ely SG Museum

Graves, 2000

CVMA

APPENDIX 50 Dated parallels BARDNEY

Stylistic dating	Spectrum	Decoration	Site	Date	CMVA	Info	Site	Date	CMVA	Info	Site	Date	CMVA	Info	
C12/13	BA18 murrey	Figurative detail?	Canterbury Cathedral	e.C13	Michael, p. 109	hand detail	Canterbury Cathedral	l. C12	Michael, p. 50, cover	horse detail					
2nd Q C14	BA6	Diaper	Eaton Bishop	1330-35	14741	Bottom middle	Eaton Bishop	1330-35	14739, 14749		York Minster	l.C13/e.C14	3665		Chapter House
	BA11	Grisaille	Eaton Bishop	1330-35	2902		Credenhill	1306/7	2921		Sempringham	l. C13/e. C14	Graves, fig. 173		
	BA4	Border pattern	Eaton Bishop	1330-35	14741, 2902		Merton Coll	1310-11	10003						
	BA13	Border pattern?	Eaton Bishop	1330-35	2902		Teweksbury	1338-40	1843		Eaton Bishop	1330-35	20133		
	BA23 blue	Plain													
	BA5	Stickwork	Eaton Bishop	1330-35	14741, 14739	background	Teweksbury	1338-40	1855		Stanford-on Avon	1330-50	1552		
	BA2 striated red	Beading	Stanford on Avon	1324-30	197	Cloak pattern	York Orderof G of Semp	C14	Graves, fig. 195 (330)	In reserve					
	BA22	Plain													
m-l C15	BA14	Scratched shading	East Harling	1465-80	Baker:52	Scratchy shading	Saxlingham, Nethergate	l.C14/e.C15	14619	same hatching					
	BA7 blue	Diaper	East Harling	1465-80	14371, 72, 76, 15851	Diaper, cloak trim									
	BA8 blue	Diaper	East Harling	1465-80	14376										
	BA24 blue	plain													
	BA25 green	indistinct													
	BA21	Plain													
	BA1	Diaper	Goodramgate, York	m-l.C15	18410		Coslany, Norwich	1480	20565	squiggles					
	BA9	Diaper	St Martin le Grand	1443-50	18172		Goodramgate, York	1471	18354						
	BA15	Architectural detail	St Martin le Grand	1443-50	18205, 18166	aspects of	East Harling	1465-80	14371						
	BA16	Architectural detail	St Martin le Grand	c. 1442	18175	aspects of	Goodramgate, York	1471	18354						
	BA20	Architectural detail				aspects of; stipple shading									
	BA3 red flashed	Diaper/border	East Harling	1465-80	14376	cross hatching	East Harling	1465-80	11708	Blue					
	BA10 blue	Diaper	East Harling	1465-80	14370		St Martin le Grand	1443-50	18205, 18166						
	BA19	Plain				FRE (fire rounded edge)									

Bibliography

Michael, 2004

Graves, 2000

Baker, 1978

CVMA

APPENDIX 51 Dated parallels BORDESLEY

Stylistic dating	Sample no.	Decoration	Site	Date	CMVA	Info	Site	Date	CMVA	Info	Site	Date	CMVA
e C13	B1	SLG	Lincoln Cathedral	e. C13	210	trefoil head, XH	Waterperry		9948	like all SLG	also has plain grisaille		
	B2	SLG	Westwell	e. C13	7386	Single berry	Lincoln Cathedral	e. C13	7408		Stodmarsh, l.l. C12		5856
	B5	Open beading/SLG	Salisbury Cathedral	e.-mid C13	9954	Motifs together	Canterbury Cathedral	1213-20	2934	Quatrefoil	St Andrew's	C13/14	Graves, fig. 172, no. 196
	B7	SLG	Salisbury Cathedral	e.-mid C13	9954								
	B8	SLG	Salisbury Cathedral	e.-mid C13	9954		LC, N trans		233	curling			
	B17	Open beading	Salisbury Cathedral	e.-mid C13	9954		Canterbury Cathedral	1213-20	2934				
l C13	B18	Open beading/SLG	Salisbury Cathedral	e.-mid C13	9954	motifs together							
	B46M green	Grisaille roundel	Stanton Harcourt	1260-75	3312		Chartham St Mary	1294	5472				
	B36 blue plain	Plain											
e-m C14	B12	Strapwork	Bere Ferrers	c.1334	6698		Wells Cathedral	e. C14	7976				
	B16	Naturalistic grisaille	Kingerby	m.C14	2065	Lincs.	York Minster		Marks, fig. 117	Chapter House, late C13	unveined fruiting leaves, as Kerr, Bradwell abbey, Med A, vol 30		
	B20	Diaper	Wells Cathedral	1335-45	8030		Tewkesbury	1338-40	1855				
	B24	Fleur de Lys	Wells Cathedral	1325-30	3376, 8030 & 7025		Merton Coll	e.C14	10006				
	B29	Architectural	Wells Cathedral	e. C14	3368		York Minster	e. C14	SGN n27	Penitencer's Window	Eaton Bishop	1330-35	14741
	B33	Grisaille	Bere Ferrers	e. C14	6472		Wells Cathedral	e. C14	7977	curved strapwork	Tewkesbury	1338/9	
	B37 amber	Architectural	Fladbury	1330s	2888		Merton College	e. C14	3307, 6059				
	B38 amber	Architectural	Fladbury	1330s	2888		Merton College	e. C14	3307, 6059				
	B44 amber	Foliate	Bere Ferrers	c.1334	6994		Tewkesbury	1338-40	1855		Pettistree	e. C14	6985
	B10	Naturalistic grisaille	Tewkesbury	1338-40	1761	dated by B13 (not analysed)	Bayham Abbey	C14	Kerr, 1985				
	B27	Heraldic	Merton College	e.C14	4035		Credenhil	c. 1300	2921		St Denys	1350	18428
	B28 blue	Drapery	Deerhurst	e.C14	20074	Glos.	Beckley	e-m. C14	5216		Westbere	e. C14	5947
	B41	Plain											
	B42	Plain bull's eye											
	B43	Plain											
	B11	Naturalistic grisaille	Tewkesbury	1338-40	1761	dated by B13 (not analysed)							
	B14	Naturalistic grisaille	Wells Cathedral	1335-45	8017		Stanton St John	1275-1300	3515		Westbere	e. C14	5947
	B15	Naturalistic grisaille	Dorchester Abbey	c. 1340	6947		Merton College	e.C14	3981		Westbere	e. C14	5947
	B30	Architectural	Wells Cathedral	1335-45	3368		Aldwincle	1310-30	1383		Eaton Bishop	1330-35	14741
	B47M	Fleur de Lys	Wells Cathedral	1325-30	3376, 8030 & 7025		Merton College	e.C14	10006		Westbere		5947, 5948
	B23 yellow	Naturalistic grisaille	Wells Cathedral	1335-45	8030		Exeter Cathedral	1300-10	33				
	B35 blue	Architectural	Eaton Bishop	1330-35	14747, 2908	streaky brushwork	York Minster	e. C14	3823				
	B40 red plain	Plain											
	B19	Stickwork border	Tewkesbury	1338-40	1855	long lived	Westbere	e. C14	5947	Canterbury Cathedral	l. C13		Michael, p. 32
First half C15	B21	Seaweed diaper	St Martin le Grand	c.1442	18239		Thurcaston, Leic	c.1425		donor, died 1425			
	B26	Angel feathers	Westbere	e. C14	5947								
	B31	Architectural	St Martin le Grand	c.1442	18157		Wrangle	1410-30	23323				
	B32	Architectural?	St Martin le Grand	c.1442	18157		Gt Malvern Priory	m. C15	9029				
	B45M	Boss	Haddon Hall	1427	22607, 22590		Waterperry	e-m.C15	10153				
	B48M	Architectural	St Martin le Grand	c.1442	18157								
	B39 SS	Architectural	St Martin le Grand	c.1442	18157								

Bibliography

SGN York Minster Stained Glass Navigator

Graves, 2000

Kerr, 1985

CVMA

Stylistic dating	Spectrum	Decoration	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info
l. C12	H41 blue	Drapery	Canterbury Cath	l. C12	Michael, p. 61, 90, 96	Typological \	York Minster	l. C12	4591	Sleeve				
e-m C13	H18	SLG	Lincoln Cathedral	e.C13	7434	lobes, XH	Salisbury Cathedral	e-mid C13	9954	Semp like				
	H15	Strapwork	Salisbury Cathedral	e-m. C13	9949									
	H17	SLG	Salisbury Cathedral	e-m. C13	9949, 10246	Upright trefoil								
	H19	SLG	Lincoln Cathedral	e.C13	007434, 024940		Salisbury Cathedral	e-mid C13	9954					
m C14	H31	Naturalistic grisaille	Kingerby	m. C14	2065		Eaton Bishop	m. C14	2908		All Saints, Yo	c. 1335-50	5337	
	H32	Vegetal	Lowick	e-m.1310-4	1360		Canterbury Cathedral	l.C14/e.C15	996					
	H52	Gothic lettering	York Minster	c.1340	3689									
	H14 SS	Architecture	York Minster	e. C14	11914	detail								
	H56 SS	Trefoil pattern	Kingerby	m. C14	2065	finial	Fishergate	m. C14	Graves, fig. 175 (214)					
	H65 SS	Naturalistic grisaille	Kingerby	m. C14	2065, 7039, 20406									
	H85 SS	Border pattern	York Minster	m. C14	11951, 11938		Kingerby	1345-50	20406	silver stain	All Saints	m. C14	5337	Long lived
	H87 SS	Architecture	Kingerby	1345-50	20406		Eaton Bishop	1330-35	14741					
	H197	plain												
	H251	plain												
	H253	plain												
	H255	plain												
	H256	plain												
m C15	H53	Gothic lettering	St Martin le Grand	c.1442	18181		St Martin le Grand	c.1442	18162, 18150	Also see Gt Malvern for all arch, m.C15				
	H55	Architecture	St Martin le Grand	c.1442	18183	Crocket								
	H57	Vegetal	Great Malvern Priory	m. C15		detail								
	H82	Architecture	Great Malvern Priory	m. C15	10169	detail	St Martin le Grand	c.1442	18181		Holy Trinity, York		18354	
	H89	Gothic lettering	Great Malvern Priory				Browne's Hospital, Stamford	c. 1475	6339		York Minster	1405-08	4782	
	H54	Lettering	Margaretting	m. C15	25242, 25246		Clavering	c.1450	25565		All Saints, Yo	c. 1412-28	5237	Chancel
	H59	Foliate	No C15 eg											
	H102	Plain bull's eye												
	H91	Floor Tiles	St Martin le Grand	c.1442	18153		Gt Malvern Priory	e. C16	10905	1601				
	H6 red	Diaper	St Martin le Grand	c.1442	18168									
	H8 red	Diaper	St Martin le Grand	c.1442	18168									
	H9 red	Seaweed diaper	St Martin le Grand	c.1442	18168									
	H43 blue	Seaweed diaper	Holy Trinity, York	1471	Baker, pl. 60									
	H46 blue	Diaper	St Martin le Grand	c.1442	18239									
	H47 blue	Diaper	St Martin le Grand	c.1442	18239									
	H49 blue	Diaper	St Martin le Grand	c.1442	18239									
	H27	Decoration	Gt Malvern P	m.C15	9032	cloak pattern	York Minster	1414	10432		St Martin le	1443-50	18196	Border
	H92	Floor Tiles	Beauchamp Chapel	1447-64	11649		Browne's Hospital, Stamford	c. 1475	6339		York Minster	1405-8	4782	
	H72 SS	Foliate/arch detail	York Minster	1414	4988									
	H75 SS	unknown detail	?			PG, fig. 276								
	H79 SS	Architecture/masonry	St Martin le Grand	c.1442	18157, 18239	Borrom R								
	H84 SS	Architecture?	St Martin le Grand	c.1442	18170									
	H50	Gothic lettering	St Martin le Grand	c.1442	18162, 18150									
	H69 SS	Rosette border	St Martin le Grand	c.1442	18164		Malvern	m.C15	9032					
	H70 SS	Rosette border	St Martin le Grand	c.1442	18164									
	H71 SS	Open beading	All Saints, York	1410	Baker, pl. 67	Long lived	Beauchamp Chapel, Warwick	1447-64	11612, 11649					
	H74 SS	Architecture?	St Martin le Grand	c.1442	18181, 18157, 18162	Scratchy								
	H76 SS	Architecture	St Martin le Grand	c.1442	18173									
	H81 SS	Architecture	East Harling	l. C15	15851	Crockets, tur	Wrangle	1410-30	23303					
	H84a SS	Architecture	St Martin le Grand	c.1442	18157									

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CVMA

Stylistic dating	Sample number	Decoration	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info
e-m. C13	L1	SLG	Westminster Abbey	e. C13	20503	Marks, fig. 102c	Salisbury cathedral	e-m. C13	10185	Drawings				
	L6	SLG	Salisbury Cathedral	e-m. C13	9954	N16 N transept								
	L9	SLG	Salisbury Cathedral	e-m. C13	9951	curling stems	West Horsley	1210-25	Baker, pl. 20		St Gilbert of Sempringham		Graves, fig. 169	Parallels to West Horsley, Surrey
	L11	SLG	Stanton Harcourt	m-l. C13	2213		Lincoln Cathedral	e-m C13	2120		Salisbury Cathedral	e.-m. C13	10246	
	L12	SLG	Salisbury Cathedral	e-m. C13	9949	split stem?	Lincoln Cathedral	e. C13	7414					
	L13	SLG	Stanton Harcourt	m-l. C13	2213		Lincoln Cathedral	e-m C13	2120		Salisbury Cathedral	e.-m. C13	10246	
	L16	Open beading	Salisbury Cathedral	e.-m. C13	9954		Canterbury Cathedra	l. C12	3000	long-lived, C12-14	York Minster	e. C14	4314	
	L18	Open beading	Salisbury Cathedral	e.-m. C13	9954		Canterbury Cathedra	l. C12	3000	long-lived, C12-14	York Minster	e. C14	4314	
	L35	Plain												
	L36	Plain												
	L2	SLG	Lincoln Cathedral	e. C13	2127	curving								
	L5	SLG	Salisbury Cathedral	e.-mid C13	9954	little flick								
	L7	SLG	Salisbury Cathedral	e.-mid C13	9954	little flick	Stanton Harcourt	1250-80	3312	berries	Stanton St John, Oxon	c.1275-1300	10062	
	L8	SLG	Lincoln Cathedral	e-m. C13	2120									
	L10	SLG	Salisbury Cathedral	e.-mid C13	9954		Stanton Harcourt	1250-80	3312	berries	Stanton St John, Oxon	c.1275-1300	10062	
	L14	SLG	Lincoln Cathedral	e.C13	007434, 24940									
	L19	Open beading	Lincoln Cathedral	e. C13	2156		Canterbury Cathedra	l. C14	Crewe, fig.11					
	L26	Lombardic lettering	Lincoln Cathedral	c.1250	2126		Credenhill	L. C13	2921		York Minster	e. C14	YM Navigator	Martyrdom Window
	L43	SLG	Lincoln Cathedral	e.C13	7434, 24940	XH								
	L44	SLG	Lincoln, Salisbury, York Minster	e-m C13		generic XH								
	L32 striated	Plain		C12-C14										
	L33 amber	Plain												
	L3	SLG	Salisbury Cathedral	e.-mid C13	9954, 9949	Spurs								
	L4	SLG	Salisbury Cathedral	e.-mid C13	9954, 9948	curling								
C14/15	L15	SLG replacement	Lincoln Cathedral	e. C13	7437									
	L20	Border pattern	Beauchamp chapel, Warwick	1447-64	11658	aspects of nimbus								
	L21	Border pattern/fig	Merton College	l.C14/e.C15	6343, 6356	aspects of	Holy Trinity, Goodra	1471	18358	hair/aspects of				
	L22	Border pattern/fig	Merton College	l.C14/e.C15	6343, 6356	aspects of	Holy Trinity, Goodra	1471	18358	hair/aspects of				
	L40	Cross hatching replacement	Lincoln Cathedral	e. C13	7434									
	L41	Cross hatching replacement	Lincoln Cathedral	e. C13	7434									
	L42	Cross hatching replacement	Lincoln Cathedral	e. C13	7434									
	L31 red flashed	Plain												
	L39	Plain												
	L734	Plain												
	L806	Plain												
	L822	Plain												
m C15	L23	Tracery pattern	Long Melford	m-l C15	11297		Clavering	c.1400	25581					
	L24	Gothic lettering	Gt Malvern P	m.C15	9032		Wrangle	1410-30	23380, 23367					
	L25	Gothic lettering	Gt Malvern P	m.C15	9032		Wrangle	1410-30	23380, 23367					
	L27	Architecture?	Gt Malvern P	m.C15	11090	stipple shading								
	L28	Tonsure	Gt Malvern P	m.C15	11058, 10880		St Martin le Grand	c.1442		Nave, north window				
	L34 blue	Drapery	Gt Malvern P	m.C15	1106		Clavering	l. C15	l. C15					
	L29	Half rosette	Goodramgate, York	1471	18353		Clavering	l. C15	Baker. Pl. 63	half rosette				
	L30	Architecture	Gt Malvern P	m.C15	11058									
	L37	Plain												
	L38	Plain												
	L702	Plain												
	L714	Plain												
	L719	Plain												

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CVMA

APPENDIX 54 Dated parallels RIEVAULX

Stylistic dating	Sample number	Decoration	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info
e-m. C13	R6	SLG	Salisbury Cathedral	e-mid C13	9954	curving								
	R7	SLG	Lincs Cath Angel Choir	e. C13		multi-lobe								
	R8	SLG	Salisbury Cathedral	e-mid C13	9954	spur	Lincoln Cathedral Angel Choir	1250-80	24526	could be early C13				
	R9	SLG	Salisbury Cathedral	e-mid C13	9954		LC, N trans		233	curling	LC Angel Choir	1250-80	24526	could be early C13
	R10	SLG	Salisbury Cathedral	e-mid C13	9954	like Sempringham								
	R12	SLG	Salisbury Cathedral	e-mid C13	9954		LC, N trans		233	curling				
	R13	SLG	Canterbury Cathedral	e. C13	Baker pl. 1	pineapple variation								
	R14	SLG	Salisbury Cathedral	e-m.C13	9949	double-headed	Sempringham	C13	Graves, fig. 171 (190)					
	R19	Linear stickwork	Canterbury Cathedral	l. C13	Michael, p. 32	amber, drapery detail	Lincoln Cathedral	l.C13	24585		Stanton Harcourt	1250-80	3312	
	R2	Cursive foliage	Canterbury Cathedral	1213-20	748	Adam, foliage	LC Angel Choir	1250-80	24526					
	R58 murrey	Drapery	Canterbury Cathedral	e.C13	Baker pl 7									
	R62	Plain												
C13/14	R17	Naturalistic grisaille	YM Ch Hs	e.C14	22238		Merton College	e. C14	4134, 9987	Ayres redated e.C14	Exeter Cathedral	1303	108	Choir, mixed date, figures 1303
	R44 murrey/amber	Grisaille	Eaton Bishop	C13/14	Baker, pl. 42, 249, 250									
m C14	R4	Architectural ?	Eaton Bishop	m. C14	14747	architectural	Deerhurst	e-m. C14	20074	Architectural	More C15 eg Goodramgate			
	R5	Open beading	York Minster	e. C14	4314		Canterbury Cathedral	l. C12	3000	long-lived, C12-14	Salisbury Cathedral	e-m. C13	9954	
	R20	Linear stickwork	Tewkesbury Abbey	1338/40	1860		Sempringham	C14	Graves, fig. 195	Elements of PG:407	Exeter Cathedral	e. C14	3	elements of
	R36	Diaper	Tewkesbury Abbey	1338/40	1855		St Andrew's Priory York	C13/14	Fig 203b PG Semp:416	Red parallel	York Minster		Graves, fig.179:235	
	R46	Open beading	Salisbury Cathedral	e.-m. C13	9954		Canterbury Cathedral	l. C12	3000	long-lived, C12-14				
	R1 amber	Grisaille	Bere Ferrers	c.1334	6994		Deerhurst	e-m. C14	20074					
	R53 blue	Diaper	Eaton Bishop	m.C14	14747	green	St Andrew's Priory, York	e-m. C14	Graves, fig. 179 (245)	nXXX	Sempringham S18		Graves, fig 221	circle background motifs
	R3	Linear stickwork	Deerhurst, Glos	e.C14	20074		Gloucester Cathedral	c.1350	Crewe, p. 12		Marsh Baldon, Oxon	C14	Baker, pl.38	
	R11	Foliate	Tewkesbury	1338/40	1855		Merevale	m. C14	13924					
	R26	Fleur de Lys	Merton Coll	e.C14	4035	used a lot after c.1340 PG.410	Checkley, Staffs	1320	21469					
	R35	Architectural	Kingerby, Lincs	1345-50	20406		Stanford-on-Avon	C14 1st half	20898		York Minster	C14 1st half	SG Navigator	Pilgrimage Window
	R45 green	Cursive border	Eaton Bishop	m.C14	20124									
	R50 pot red	Diaper	York Minster	1339	3707									
	R51 blue	Diaper	Tewkesbury Abbey	1338/9	Baker, pl. 27, 30		Wells Cathedral	1325-33	Baker, pl. 34		York Pilgrimage Window N25, panel 5b	1st half C14	YM SGN	
	R52 blue	Diaper	Christ Church, Oxon	m.C14	3445	scratching	Kingerby	m.C14	7039 & 2065	scratching	St Denys, York	c. 1350	19473, 18473	
	R63 blue	Spirals, border	Tewkesbury Abbey	c.1338-40	1843									
	R24	Face	Canterbury Cath	1410	Baker pl. 47		Marsh Baldon,	C14	Baker pl. 37	aspects of	Sempringham	l. C14/15	PG p. 473	
	R25	Bird	Eaton Bishop	1330-35	20130		York Minster	e. C14	SG Navigator	Pilgrimage Window,	Ryther N. Yorks	C14 1st 1/2	no no.	
	R55 green	Foliate	Madley	c1350	22911, 22916	aspects of	Eaton Bishop	1330-35	14747		Tewkesbury	1338/9	1855	Jesse, part of below
	R56 green	Foliate	Madley	c.1350	22911, 22916	aspects of	Eaton Bishop	1330-35	14747					
	R54 green	Plain									c. 1340			
m-l C15	R15	Foliate	Margaretting	m.C15	25262									
	R18	Foliate/berries	Holy Trinity, Goodramg	1471	18399		Margaretting	m.C15	25262					
	R23	Figurative	East Harling	l.C15	15854/15866/14374		Canterbury Cathedral	1482-87	1071		Canterbury Cathedral	1410	Baker, pl:47	
	R29	Gothic lettering	Margaretting	m.C15	25262		St Martin le Grand	c.1442	18162, 18150					
	R30	Gothic lettering	Margaretting	m.C15	25262		St Martin le Grand	c.1442	18162, 18150		Gt Malvern	m.C15	11091	
	R31	Gothic lettering	Margaretting	m.C15	25262		St Martin le Grand	c.1442	18162, 18150		Gt Malvern	m.C15	11091	
	R21	Hand	Holy Trinity, Goodramg	1471	18358		St Martin le Grand	c.1442	18168					
	R22	Foot	Holy Trinity, Goodramg	1471	18358		Gt Malvern	e.-m.C15	10887		Canterbury Cathedral	1482-87	1482-87	
	R27	Gothic lettering	Margaretting	m.C15	25255		East Harling	l.C15	15867					
	R28	Gothic lettering	Margaretting	m.C15	25255		East Harling	l.C15	15867					
	R38	Architecture	Holy Trinity, York	1470-75	18385	East Window	Gt Malvern	e-m.C15	11090		E Harling	l.C15	14374 & 15854	SS
	R39	Architecture	Holy Trinity, York	1470-75	18385	East Window	Gt Malvern	e-m.C15	11090		E Harling	l.C15	14374 & 15854	SS
	R41	Architecture	Holy Trinity, York	1470-75	18385	East Window	Gt Malvern	e-m.C15	11090		E Harling	l.C15	14374 & 15854	SS
	R43	Architecture	Gt Malvern	m.C15	11058		Holy Trinity, York	1470-75	18385	East Window	E Harling	l.C15	14374 & 15854	SS
	R32 SS	Foliate/background/ca	Margaretting	m.C15	25239		Long Melford	m.-l.C15	11297					
	R33 SS	Architecture	Holy Trinity, York	1470-75	18385	East Window	Wrangle	1410-30	23310	architectural	York Minster	c. 1414	4940	
	R37 SS	Architecture	Gt Malvern P	m.C15	11058, 23323									
	R60	Plain												
	R61	Plain												
	R40	Architecture?	Great Malvern Priory	e.-m. C15	10973/11090		East Harling	L.C15	15854	stipple shading				
	R42	Architecture	Great Malvern Priory	e.-m. C15	10973/11090		East Harling	L.C15	15854					
	R48 red flashed	Border pattern	Beauchamp Chapel, Wi	1447-64	11614	feathered	Wrangle	1410-30	23380	textured, left				
	R34 SS	Foliate/background	Margaretting	m.C15	25242		East Harling	L.C15/1480	15852, 15854					

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APPENDIX 55 Dated parallels WHITBY

Stylistic dating	Sample number	Decoration	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info	Site	Date	CVMA no.	Info
e-m. C13	W1	Trefoil, line down stem, XH	Salisbury Cathedral	e.-m. C13	9954	illustration	Lincoln Cathedral	e-m. C13	7408	Also Marks fig 103, 114	Lincoln Cathedral	e.-m. C13	10185	Drawings
	W4	Curling trefoil	Salisbury Cathedral	e.-m. C13	9954	illustration	Stanton Harcourt	1250-80	3312	Marks, fig. 114 (1260-75)				
	W5	Open beading in border	Salisbury Cathedral	e.-m. C13	9954	illustration	Canterbury Cathedral	l. C12	3000	long-lived, C12-14	Dorchester	e. C14	6946	
	W9	Trefoil head	Lincoln Cathedral	e.C13	24526		YM, 5 sis, Salis		PG:188					
	W27 blue	plain												
	W31	plain												
	W2	Curling stems and XH	Lincoln Cathedral	e.C13	10037		York Minster	1250-60	3628	Five Sisters	Stanton Harcourt	1250-80	3312	Marks, fig. 114 (1260-75)
	W3	Trefoil, XH	Lincoln Cathedral	e.C13	10034	Line down centre of trefoil	Westwell	e. C13	7386	Drawings	Salisbury Cathedral	e.-m. C13; 1260-66	10185; Brown, p. 91	Drawings
	W6	Open beading in border	Salisbury Cathedral	e.-m. C13	9954		Canterbury Cathedral	l. C12	3000	long-lived, C12-14	Dorchester	e. C14	6946	
	W10	Berries	Salisbury Cathedral	e.-m. C13	10185, 9954	illustration	Salisbury Cathedral	1225-58	Brown, p. 87		Stanton Harcourt	1250-80	3312	Marks, fig. 114 (1260-75)
C13/14	W8	Leaf & strapwork	York Minster Chapter House	l. C13	22268	illustration	Merton College	e. C14	4134, 3990		Bere Ferrers	e. C14	6472	
	W11	Cross/dot in reserve	Stamford-on-Avon	c.1330	20919		York (Order of St Gilbert)	C14	Graves, fig 195, no. 337	Similar, no circles on cross-ends				
	W15	Band/dot in reserve	E Hagbourne, Oxon	1340	Baker pl. 23		Wells Cath	1335-45	8030	check	Marsh Baldon	C14	Baker, pl. 38	
	W25 red streaky	plain												
	W26 red streaky	plain												
	W7	Wavy	Tewkesbury	1338-40	1855	aspects of	St Denys, York	c. 1350	18473	Architectural detail?				
	W17	Patterned quarry/quatrefoil	York Order of G or Semp	C14	Graves, fig. 175-77	half panel in Whitby Museum								
	W18	Patterned quarry	York Order of G or Semp	C14	Graves, fig. 175-77									
	W19	Patterned quarry	York Order of G or Semp	C14	Graves, fig. 175-77									
	W28 blue	plain												
first half C15	W16	Flower	St Martin le Grand	c.1442	18170	silver-stained	wrangle	1410-30	23313, 23367		York Minster, GEW	1405-8	SG Navigator	St. John of Beverley
	W13	Architectural	Cassiobury Park	1450	V&A									
	W14	unknown	?											
	W20	Arch/flooring	Beauchamp Chapel	1447-64	11649	bottom of panel								
	W21 flashed red	plain												
	W24 flashed red	plain												
	W22	Architectural highlights	Great Malvern Priory	e-m. C15	11090		East Harling	LC15	15854					
	W30	plain												
	W33	plain												

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The Rose Window

CVMA

Alcester C13, no. = 15		
Feature	**No.**	**Description**
Weathering	15	All samples are weathered, in most cases severely with a crust extending over the surface and edges of the glass. Some of the crust has cracked or flaked away, particularly around the edges exposing the glassy core (figure xx). Seven samples are coated with surface concretions
In-situ	9	Nine samples show external pitting of which three also retain a lead shadow.
Naturally coloured	10	Pale green
Coloured	5	There is one streaky red glass (Alc 65a) and four amber: two are decorated border glasses and a further two amber glasses are painted with inscriptions in the Lombardic style, and which are probably from the same panel (Alc 44, Alc 46)
Grozed edges	9	Nine samples have between one and three grozed edges; Alc 0742 is coarsely grozed
Original quarry shapes		Original quarry shapes are straight-sided and curving rectangles: Alc 0742 is an undecorated border piece; Alc 73c is a decorated border piece; Alc 47 is arched-shaped painted with Lombardic lettering
Forming technique	1	73c has indents on its exterior side as evidence of broad production
Workshop practice	2	Alc 0742 contains inclusions of un-melted batch. Alc 65a has an uneven surface and tool marks on the exterior side where the glass has been manipulated (figure xx)
Thickness	15	The pale green glasses range in thickness 3.4- 5 mm and the coloured glasses range from 2.0-4.5 mm. The four amber glasses are on average the thinnest (2.7 mm) and the red glass, Alc 65a is the thickest (4.5mm).
Surface area	15	55 cm^2
Decoration	13	All decoration is painted with red-brown paint.

Alcester C13/14, no. = 1		
Feature	**No.**	**Description**
Weathering	1	Localised patches of crust over its interior surface
In-situ	1	Pitting and lead shadows on the exterior side
Naturally coloured	1	Pale green
Grozed edges	1	Two grozed edges along the length
Original quarry shapes	1	Long rectangular, probably a border piece
Forming technique	0	There is no evidence of forming technique
Workshop practice	1	Slightly undulating with inclusions visible on the interior surface.
Thickness	1	The sample is 3mm thick
Surface area	1	3 cm^2
Decoration	1	Red-brown paint.

Alcester C14, no. = 20		
Feature	**No.**	**Description**
Weathering	20	The degree of weathering within the group is variable: most of the pale green samples show only slight discolouration, such as Alc 76 and 79, while four samples are severely weathered with a crust that has flaked off in some places (Alc 74, Alc 80), and two silver-stained samples (Alc 41a and 42). All of the coloured fragments are weathered, some severely: all of the paint on Alc 53 has weathered away yet the glass retains the raised outline of the decoration (figure xx). One coloured glass and most of the pale green glasses and are coated in surface concretions.
In-situ	2	Alc 60, Alc 61, Alc 76 and Alc 79 are pitted on the exterior side
Naturally coloured	13	Pale green
Coloured	7	There is one each of blue, amber and murrey; two green and two striated red.
Grozed edges	13	The majority of the C14 group is grozed. There is one complete quarry with four original edges (Alc 90).

Original quarry shapes		Alc 90 is a freehand shape, grozed diagonally across the body incorporating one arm, which is in an orans posture, as in praying. Alc 61 is near complete sub-triangle with the apex broken off. Also present are rounded and sub-rectangular shapes; this latter fragment (Alc 68) being similar to the narrow arch-shaped fragments from the C13 described above, although it is a foliate pattern.
Forming technique	4	There are four fragments with evidence of broad glass production in the form of indentations on the exterior surface. These include three coloured fragments and one silver-stained fragment (Alc 57b, 60, 68, 41a)
Inclusions etc	2	Two fragments (Alc 41a, Alc 42) contain un-melted inclusions on their interior surface.
Thickness		All glasses in the group are between 2 and 4 mm thick.
Surface area		258 cm^2
Decoration		Five are silver-stained. The naturally coloured fragments are painted in brown paint, Alc 90 has linear stickwork detailing (figure xx)

Alcester C16, no. - 1		
Feature	**No.**	**Description**
Weathering	1	This sample is partly devitrified with localised patches of corrosion
Coloured	1	Colourless
Grozed edges	1	It has two grozed edges
Original quarry shapes	1	Part of a narrow rectangular section painted with an inscription.
Forming technique	0	There are no indicators of forming technique.
Thickness	1	The glass is very thin, 2 mm
Surface area	1	10.0 cm^2

Bardney late C12,1 sample		
Feature	**No.**	**Description**
Weathering	1	BA18 is a heavily corroded fragment with a weathered crust, flaking around the edges, and surface concretions
Coloured	1	The colour of the glass is murrey
Original edges	1	It retains one grozed edge
Original quarry shapes	0	The original quarry shape cannot be determined
Forming technique	0	No method of forming can be determined
Thickness	1	The glass is 3mm thick
Surface area		20 cm^2
Decoration	1	The glass is painted with brown paint

Bardney C14a, 2 samples		
Feature	**No.**	**Description**
Weathering	2	Both glasses are severely corroded with crusts that have flaked in places to reveal a pale green glassy core BA6 is pitted
Naturally coloured	2	Pale green
Original edges	2	BA11 has retained one grozed edge and BA6 has retained four
Original quarry shapes	1	BA6 is rectangular
Forming technique	0	The poor condition of both samples obscures any evidence of forming technique
Inclusions etc	1	Inclusions of un-melted batch can be observed on the exterior of BA6
Thickness	2	BA6 is 4 mm, BA11 is 2mm
Surface area		33 cm^2
Decoration	2	Paint colour is brown and red-brown

Bardney C14b, 3 samples		
Feature	**No.**	**Description**
Weathering	3	All three samples are extremely corroded and almost completely denuded of their weathered crust and much of the decoration
Naturally coloured	2	The glassy core in two samples is pale green (BA4, BA13)
Coloured	1	BA23 is coloured blue
Original edges	0	There are no original edges on any of the fragments
Original quarry shapes	0	No original shapes present
Forming technique	0	No evidence to suggest forming technique
Thickness	3	The thicknesses of the glasses range from 2-3.5 mm although some depth may have been lost due to flaking, particularly of BA13 and BA23
Surface area		24 cm^2
Decoration	2	Where decoration is intact it is painted brown and red-brown

Bardney C14c, 3 samples		
Feature	**No.**	**Description**
Weathering	3	They are heavily corroded with weathered crusts. BA22 is undecorated and where the crust has flaked it has a bubbly glassy core that is ridged in places
In-situ	2	Two glasses are pitted (BA2, BA5)
Naturally coloured	2	Two pale green glasses
Coloured	1	One striated red glass
Original edges	3	All glasses have retained two grozed edges
Original quarry shapes	1	BA2 is a curved border fragment
Forming technique	0	There is no evidence to suggest forming technique
Thickness	3	The samples are between 2.3-4.8mm thick
Surface area		26 cm^2
Decoration	2	Paint is brown and red-brown

Bardney C15a, 6 samples		
Feature	**No.**	**Description**
Weathering	6	All are severely corroded, two have weathered crusts (BA8, BA14) and two have surface concretions (BA7, BA24)
In-situ	0	
Naturally coloured	1	There is one colourless glass
Coloured	5	There are five coloured glasses, three blue and two green
Original edges	6	Five of the samples have grozed edges and one glass has an original fire-rounded edge
Original quarry shapes	1	BA7 is an incomplete irregular background shape and BA14 is sub-triangular
Forming technique	1	BA21 has a fire rounded edge that demonstrates broad production BA25, many large, rounded bubbles, orientation uncertain
Thickness	6	All the glasses are 3mm thick or less
Surface area		39 cm^2
Decoration	4	The four decorated fragments are painted red-brown

Bardney C15b, 8 samples		
Feature	**No.**	**Description**
Weathering	8	They are all heavily corroded with weathered crusts and BA10 is devitrified
Naturally coloured	6	Very pale green to colourless
Coloured	2	One blue (BA10) and one flashed red (BA3)
Grozed edges	2	BA19 has one grozed edge and another fragment (BA10) has two grozed edges
Original quarry shapes	0	There are no discernible original shapes
Forming technique	1	BA19 has a fire rounded edge demonstrating that it is broad glass
Thickness	8	Only one fragment is thicker than 2.3 mm (BA19), which is 3.5mm thick
Surface area		38 cm^2
Decoration	6	Decorated fragments are painted brown, and three fragments are stipple shaded (BA15, BA16, BA20)

APPENDIX 58 Technical analysis
BORDESLEY

Bordesley C13a, 7 samples		
Feature	**No.**	**Description**
Weathering	7	All fragments are severely corroded with one sample in a very fragile condition (B17). A crust extends over the edges of all samples and has in places flaked away to expose the glassy core. B7 is heavily chipped in two large areas that are also covered in a black crust
In-situ	1	B8 has pitting
Naturally coloured	1	Pale green
Coloured	0	
Grozed edges	8	Eight glasses have grozed edges, B36 has four
Original quarry shapes	1	B17 is rectangular shape and is a border piece. B18 has the same decoration and is probably, also a border fragment
Forming technique	0	Although B2 contains many small bubbles, as discussed in xxx, this shape cannot determine forming technique, and there is no other evidence in the group for how the glasses were made
Workshop practice	2	B1, B5 and B18 have inclusions of un-melted batch visible on the surface of the glass
Thickness	9	All the glasses are relatively thick, between 3-5mm
Surface area	9	74 cm^2
Decoration	8	Paint is red-brown

Bordesley C13b, 2 samples		
Feature	**No.**	**Description**
Weathering	2	Both glasses are severely corroded with a weathered crust
In-situ	1	B46 has a lead shadow
Coloured	2	Both glasses are coloured, blue (B36) and green (B46)
Grozed edges	2	B46 has two grozed edges and B36 has four
Original quarry shapes	1	B36 is a sub-rectangular border piece and B46 is one half of a roundel
Forming technique	0	There is no evidence of forming technique
Thickness	2	Both samples are relatively thick, 3.7 and 4 mm
Surface area		32 cm^2
Decoration	1	B46 is painted with red-brown paint

Bordesley C14a, 9 samples		
Feature	**No.**	**Description**
Weathering	9	All are severely corroded; two fragments have surface concretions and B12 has been consolidated with PVA
Naturally coloured	6	Naturally coloured pale green
Coloured	3	Amber coloured glasses
Grozed edges	8	All fragments except B29 have grozed edges
Original quarry shapes	3	Original shapes are a triangle/diamond (B12, B44) and freehand (B24). This latter fragment is the upper portion of a fleur de Lys and is probably an individual quarry, shaped freehand all the way around the motif
Forming technique	0	There is no evidence to suggest forming technique
Workshop practice	1	B44 has inclusions of un-melted batch on the surface of the interior side
Thickness	9	The fragments vary in thickness between 2 and 4.5 mm
Surface area		78 cm^2
Decoration	9	The paint is red-brown and is very thickly applied on B44

Bordesley C14b, 6 samples		
Feature	**No.**	**Description**
Weathering	6	All samples are severely corroded with weathered crusts. B43 is extremely degraded and has been consolidated with PVA
In-situ	3	Three samples are pitted
Naturally coloured	5	Pale green including a bull's eye
Coloured	1	One blue sample
Grozed edges	3	Three fragments have grozed edges, B10 has three
Original quarry shapes	1	B10 is in two parts that form a diamond shaped quarry. The bull's eye is roughly cut around the centre and shows no evidence of having been glazed into a window
Forming technique	4	Crown production is indicated by the tapering thicknesses
Thickness	6	All of the glasses are thick and most of them taper, for example: B41 tapers 2.5-5mm and B43 tapers 6-8mm. The bull's eye is 11mm in the centre and 3mm around the edge
Surface area		220 cm^2
Decoration	3	Red-brown paint

Bordesley C14c, 8 samples		
Feature	**No.**	**Description**
Weathering	8	All glasses in the group are severely corroded with a weathered crust extending over the edges. B15 is flaking, and B14 and B45 are in a deteriorated state and have been consolidated with PVA. B40 is devitrified in one section
In-situ	5	Five samples have external pitting
Naturally coloured	3	Naturally coloured pale green
Coloured	5	One sample each of striated red, amber and blue
Grozed edges	5	Five fragments retain two grozed edges
Original quarry shapes	2	B15 is sub-triangular and B35 is an almost complete rectangular shape
Forming technique	0	There is no evidence of forming technique
Thickness	8	Thicknesses range between 2-5mm and B47 tapers slightly. 2-3 mm
Surface area		84 cm^2
Decoration	8	All painted decoration is a red-brown colour

Bordesley C14d, 1 sample		
Feature	**No.**	**Description**
Weathering	1	B19 has a weathered crust, consolidated
In-situ	1	Pitting
Naturally coloured	1	The sample is a pale green glass
Grozed edges	1	The sample has two parallel grozed edges
Original quarry shapes	1	The original shape is sub-rectangular and is probably a border pattern
Forming technique	0	There is no evidence of forming technique
Thickness	1	B19 is 3mm thick
Surface area		6 cm^2
Decoration	1	Stickwork decoration is red-brown

Bordesley C15, 7 samples		
Feature	**No.**	**Description**
Weathering	7	All fragments from the assemblage are severely weathered. This necessitated the mounting of four samples for chemical analysis to expose the glassy core as there was no glass visible for a surface analysis
In-situ	2	B32, B39 are pitted on the exterior side
Naturally coloured	7	All glasses are naturally coloured pale green
Grozed edges	5	Five fragments retain grozed edges
Original quarry shapes	1	One original freehand shape is present, B26
Forming technique	0	Small bubbles are observed in B32, but forming process cannot be determined
Thickness	7	Thicknesses range between 2-3.5mm
Surface area		109 cm^2
Decoration	7	All seven glasses are decorated in red-brown paint and B39 is silver stained on the exterior side

Hyde C12, 1 sample		
Feature	**No.**	**Description**
Weathering	1	This is the earliest sample in the assemblage and is relatively un-corroded except for some dulling and surface concretions
Coloured	1	Blue
Grozed edges		The glass has two grozed edges
Original quarry shapes	0	
Forming technique	1	There are indents on the exterior side indicating broad production
Thickness	1	The fragment is 3mm thick
Surface area		8 cm^2
Decoration	1	The paint is red-brown

Hyde C13a, 1 sample		
Feature	**No.**	**Description**
Weathering	1	The fragment is heavily corroded with a thick crust
In-situ	1	There is pitting on the exterior side
Naturally coloured	1	The glassy core is pale green
Grozed edges	1	One grozed edge
Original quarry shapes	0	There is no indication of original quarry shape
Forming technique	0	There is no indication of forming technique
Thickness	1	The glass is 4mm thick
Surface area		6.5 cm^2
Decoration	1	Decoration is painted with red-brown paint

Hyde C13b, 2 samples		
Feature	**No.**	**Description**
Weathering	2	Both samples are heavily corroded, with a weathered crust and surface concretions
In-situ	2	Pitting
Naturally coloured	2	Base colour is pale green
Grozed edges	1	H17 retains two grozed edges
Original quarry shapes	0	There is no indication of original quarry shape
Forming technique	0	There is no indication of forming technique
Thickness	2	The glasses are very thick, 4 mm and 5 mm
Surface area		10.5 cm^2
Decoration	2	Paint for both samples is red-brown

Hyde C13c, 1 sample		
Feature	**No.**	**Description**
Weathering	1	The fragment is heavily corroded
In-situ	1	Pitting on the exterior surface
Naturally coloured	1	The glass is pale green
Grozed edges	1	One grozed edge
Original quarry shapes	0	There is no indication of original quarry shape
Forming technique	0	There is no indication of forming technique
Thickness	1	It is 4 mm thick
Surface area		8 cm^2
Decoration	1	Paint colour is red-brown

Hyde C14, 13 samples		
Feature	**No.**	**Description**
Weathering	13	The condition of the group is varied ranging from fragments that are heavily corroded with a weathered crust and surface concretions to fragments with minor corrosion, for example all five undecorated fragments
In-situ	1	H32 is pitted
Naturally coloured	13	All glasses are naturally pale green
Grozed edges	9	Nine fragments retain at least one grozed edge: H32 has three
Original quarry shapes	3	H32 is sub-rectangular and other original quarries are a rectangular border fragment (H255) and a curved shoulder pane (H85)
Forming technique		H32 is 5-7mm thick and H85 is 3-4 mm thick, and both are probably formed by the crown method. Although H82 has long, wide bubbles in a linear alignment, it is difficult to say with confidence that it is broad glass – see section xx bubbles.
Thickness	13	Most of the fragments are relatively thick with only two below 3 mm and five measuring 4 mm or above. Two glasses taper in profile: H32 is 5-7mm thick and H85 is 3-4 mm thick
Surface area		106.5 cm^2
Decoration	8	Eight glasses are decorated with red-brown paint and five glasses are also silver stained (H14, H56, H65, H85, H87)

Hyde C15a, 5 samples		
Feature	**No.**	**Description**
Weathering	5	The glasses are moderately corroded, H53, H89 have surface concretions
In-situ	2	H53, H89 are pitted
Naturally coloured	5	All of the glasses in the group are naturally coloured pale green
Grozed edges	0	There are no grozed edges
Original quarry shapes	0	There are no identifiable original shapes
Forming technique	0	There is no indication of forming technique
Thickness	5	All glasses are 2-4 mm thick
Surface area		23 cm^2
Decoration	5	Decoration is painted in red-brown paint; H82 is has smear shading and H89 is silver stained

Hyde C15b, 3 samples		
Feature	**No.**	**Description**
Weathering	3	H54 is severely weathered with surface concretions; H102 is mildly corroded and H59 is in good condition
In-situ	1	H54 is pitted
Naturally coloured	3	The two fragments and the crown glass bull's eye are all pale green.
Grozed edges	0	There are no grozed edges. The bull's eye has been roughly cut out and shows no evidence of having been glazed
Original quarry shapes	0	No quarry shapes are present.
Forming technique	1	There is one crown glass bull's eye, but the remaining two fragments do not show evidence of forming technique .
Thickness	3	The bull's eye measures 3mm thick at the out edge and12 mm thick in the centre. The two other fragments are 2.5 mm and 3mm thick
Surface area		56.5 cm^2
Decoration	2	Paint is red-brown

Hyde C15c, 7 samples		
Feature	**No.**	**Description**
Weathering		All the glasses are in good or mildly corroded condition. H43 and H47 have surface concretions
Naturally coloured	0	
Coloured	7	Seven coloured glasses: four blue (H43, H46, H47, H49) and three flashed red (H6, H8, H9).
Grozed edges	3	There are three glasses with one grozed edge
Original quarry shapes	0	No original shapes are present
Forming technique	3	H43, H47, H49 have indents on the exterior as evidence of broad production
Thickness	8	All of the glasses are 2.5 mm thick or less
Surface area		33.5 cm^2
Decoration		The glasses are painted with red-brown paint

Hyde C15d, 7 samples		
Feature	**No.**	**Description**
Weathering	7	All are relatively unweathered with only small patches of corrosion (H75) and surface concretions (H27)
Naturally coloured	7	All glass is colourless or very pale green
Grozed edges	3	Three glasses are grozed on one edge
Original quarry shapes	0	There are no identifiable original quarry shapes
Forming technique	1	H91 and 92 have indents on one side indicating broad production
Thickness	6	The thickness of the glasses ranges from 1.2 mm to 3 mm
Surface area		22.5 cm^2
Decoration	6	Five glasses are painted red-brown, and two glasses are dark brown/black, and as above, represent black and white tessellated flooring. Four glasses are silver-stained (H72, H75, H79, H84)

Hyde C15e, 8 samples		
Feature	**No.**	**Description**
Weathering	8	All glasses are in good condition, two glasses have surface concretions
Naturally coloured	8	All glasses are colourless
Grozed edges	3	Three glasses have grozed edges
Original quarry shapes	0	There are no original shapes present
Forming technique	1	H69 has indents on the exterior side as evidence of broad production
Thickness	8	All glasses are <3.3 mm thick
Surface area		20.5 cm^2
Decoration	8	Seven glasses are decorated with red-brown paint and one glass, which depicts Gothic lettering, is painted in dark brown/black (H50). Seven fragments are silver-stained. H74 is highlighted with stipple shading

Louth Park C13a, 10 samples		
Feature	**No.**	**Description**
Weathering	10	Approximately half of the group is heavily corroded with a weathered crust, and the other half of the group is either moderately corroded or in good condition
In-situ	2	L6, L11, L12, L13, L36 have pitting
Naturally coloured	10	All of the glasses are pale green
Grozed edges	7	Seven fragments retain at least one grozed edge, L11 has four
Original quarry shapes	4	Two quarry shapes are identifiable: sub-rectangular border pieces (L11, L16, L18) and curved (L9)
Forming technique	2	L35 and L36 taper significantly indicating crown production poss
Workshop practice	1	L36 has a prominent tool mark along its edge
Thickness	10	The thickness of the decorated glass is between 2.8-4 mm and the two plain glasses taper 2 – 5 mm
Surface area	10	83.75 cm^2
Decoration	8	Decorated glasses are painted red-brown, L35 and L36 are plain

Louth Park C13b, 10 samples		
Feature	**No.**	**Description**
Weathering	10	As above, the condition of the group is varied, from severely corroded with a weathered crust (L2) to good (L14).
In-situ	1	L2 is pitted
Naturally coloured	10	All glasses are pale green
Grozed edges	7	Seven fragments have grozed edges
Original quarry shapes	2	Original shapes are rectangular (L19) and a triangular quarry apex (L43)
Forming technique	2	L26 and L44 have very fine indentations that is evidence of broad production
Thickness	10	Thickness ranges from 2.5 to 4.3 mm

Surface area	10	153.75 cm^2
Decoration	10	Painted decoration is red-brown. L26 has thickly applied paint and appears to be stencilled

Louth Park C13c, 4 samples		
Feature	**No.**	**Description**
Weathering	4	Both glasses are severely weathered with crusts and flaking
In-situ	2	L32 is pitted on its exterior side, L3 is pitted on its exterior side
Coloured	4	Striated red (L32) and amber (L33).
Grozed edges	3	L32 has one grozed edge
Original quarry shapes	1	No original shapes can be determined
Forming technique	1	L33 is indented on the exterior side demonstrating broad production
Thickness	4	Both glasses are relatively thick, 3.9 mm and 3.6 mm
Surface area	2	18.5 cm^2, 30 cm^2
Decoration	0	All glasses are plain

Louth Park C14/15, 12 samples		
Feature	**No.**	**Description**
Weathering	12	Approximately half of the group is in good, relatively uncorroded condition and the other half is more corroded, two heavily: L20 has a weathered crust and flaking, L40 has surface concretions
In-situ	4	L806 is pitted and L21, L41 and L39 have lead shadows
Naturally coloured	11	Pale green
Coloured	1	Flashed red
Grozed edges	11	Eleven fragments retain at least one grozed edge. There are three samples with three grozed edges (L31, L806, L822) and L39 has five
Original quarry shapes	6	L39 is a complete shield-shaped pentagon and there are five rectangular border fragments (L21, L22, L31, L734, L806)
Forming technique	4	L15, L21 and L822 have evidence of broad production in the form of indentations on the exterior side

Thickness	12	The average thickness of ten samples is approximately 3.3 mm; two plain fragments are thicker, L822 is 4.4 mm and L806 tapers 3.5-5 mm
Surface area	10	134.5 cm^2
Decoration	7	All decoration is painted red-brown. L15 and L40 have smear shading

Louth Park C15, 13 samples		
Feature	**No.**	**Description**
Weathering	13	The glasses are relatively uncorroded, L28 has surface concretions
Naturally coloured	12	12 glasses are naturally coloured pale green
Coloured	1	There is one blue fragment (L34)
Grozed edges	10	Ten fragments retain grozed edges, L702 and L714 have three
Original quarry shapes	3	L38 and L719 are sub-triangular and L28 is shaped freehand around the upper portion of a tonsured head
Forming technique	3	L37, L38 and L719 have fire rounded edges demonstrating broad production. These are all plain glasses
Thickness	13	All fragments between 2 and 3 mm thick
Surface area		142 cm^2
Decoration	10	Decorated fragments have red-brown paint and L27, L28 are stipple shaded

Rievaulx C13, 12		
Feature	**No.**	**Description**
Weathering	12	The one group of C13 glasses includes nine lightly corroded glasses and two severely corroded glasses with thick weathered crusts that have flaked around the edges, extensively in some glasses . This includes R2, a green glass that has an indented outline of the decoration left behind
In-situ	1	H8 has a lead shadow
Naturally coloured	11	Naturally coloured pale green
Coloured	1	R58 is murrey
Grozed edges	7	Seven fragments have retained grozed edges
Original quarry shapes	3	H8 and R2 are curved, H8 in an ogee shape and R19 is a rectangular border fragment
Forming technique	0	There is no evidence of forming technique in the group
Thickness	12	The fragments are thick, between 3mm and 4.8mm, with an average of 3.7 mm
Surface area		251.5
Decoration	11	One glass is undecorated (R62) and the rest of the group is painted in brown or red-brown paint, R19 in stickwork

Rievaulx C13/14, 2 samples		
Feature	**No.**	**Description**
Weathering	2	B17 has a thin corrosive layer extending to the edges and darker localised patches of corrosive material, R44 is more heavily weathered and is devitrified in places
In-situ	1	R44 is pitted
Naturally coloured	1	B17 is pale green
Coloured	1	R44 is murrey
Grozed edges	2	R44 has three grozed edges and B17 has one grozed edge
Original quarry shapes	0	No original quarry shapes are discernible

Forming technique	1	The tapering of R44 suggests crown production
Thickness		Both glasses are relatively thick, B17 is 3mm and R44 tapers 3-4.6 mm
Surface area		16
Decoration		Both are painted with red-brown paint

Rievaulx C14a, 7 samples		
Feature	**No.**	**Description**
Weathering	7	All samples are corroded with dulling and localised spots of corrosive material, and R4 also has a weathered crust and surface concretions
Naturally coloured	5	Pale green
Coloured	2	There is one blue and one amber glass
Grozed edges	5	Five of the glasses retain grozed edges
Original quarry shapes	5	Original shapes are rectangular (R5) and sub-rectangular (R20), square (R1), triangular (R36), and irregular (B4). This latter glass has a curving interior shape, straight outer edge and a pointed terminal
Forming technique	0	There is no evidence of forming technique
Thickness	7	The glasses are relatively thick, with an average of 3.9mm
Surface area		133
Decoration		All samples are decorated; paint is red-brown. Three glasses are painted in reserve: two open beading patterns (R5, R46) and one sample with stickwork detailing (R20)

Rievaulx C14b, 9 samples		
Feature	**No.**	**Description**
Weathering	9	Most of the glasses have slight weathering and dulling except for red R50, which is more degraded, and blue R63, which has a thick weathered crust. Three samples have surface concretions
In-situ	5	R3, R26, R35 and R45 have external pitting , and R26 and R51 have lead shadows
Naturally coloured	4	Four glasses are naturally coloured pale green
Coloured	5	There are three blue samples, one striated red and one green sample

Grozed edges	8	Eight glasses have between one and five grozed edges
Original quarry shapes	5	Original quarry shapes are a rectangular border piece (R63), sub-rectangular (R35), triangular (R50) and irregular (R51, R52). The irregular-shaped quarries are both complete 5-sided blue glasses with a background rinceau design
Forming technique	1	Evidence of broad glass production is in the form of a fire rounded straight edge on R52
Thickness	9	The glasses range in thickness between 2mm and 4.1mm
Surface area		104.5
Decoration	8	Decoration is painted in red-brown or dark brown paint. Six glasses are painted in reserve, one glass (R3) shows stickwork decoration over a thin wash. R45 is a finely painted rinceau or border pattern. R63 is undecorated although the thick crust obscures any possible decoration

Rievaulx C14c, 5 samples		
Feature	**No.**	**Description**
Weathering	5	R25 is relatively uncorroded and R24 is severely corroded with a thick weathered crust. R55, R56 have a thin weathered crust and are devitrified in places. The undecorated green sample (R54) is slightly iridescent
Naturally coloured	2	Two pale green glasses
Coloured	3	There are three green glasses
Grozed edges	3	Three glasses retain one grozed edge
Original quarry shapes	0	There are no discernible original shapes
Forming technique	0	There is no indication of how the glasses in this group were formed
Thickness	5	R55 and R56 are between 2.3-3.3 mm thick, R55, R56 are between 2.3-3.3 mm thick and R54 is 1.8 mm thick
Surface area		48.25
Decoration	4	Paint colour is red brown, and R25 is painted in reserve in a manner similar to four of the samples in the above C14 groups (R11, R20, R25, R26, R35) that are also of the same base glass colour

Rievaulx C15a, 6 samples		
Feature	**No.**	**Description**
Weathering	6	All glasses have dulled surfaces
In-situ	4	The three glasses painted with lettering have pitting and lead shadows on their exterior sides (R29, R30, R31); R15 has two lead shadows
Naturally coloured	6	All of the samples are naturally tinted pale green
Grozed edges	6	All samples have between one and three grozed edges
Original quarry shapes	0	No original quarry shapes can be identified
Forming technique	0	There is no evidence of forming technique
Thickness	6	The glasses range in thickness between 1mm (R29) and 4mm (R18)
Surface area		60
Decoration	6	Five samples are painted with red brown paint; R23 has dark brown paint and is stipple-shaded

Rievaulx C15b, 1 sample		
Feature	**No.**	**Description**
Weathering	1	R21 has a dulled interior surface with concretions
In-situ	1	There is pitting and a lead shadow on exterior surface
Naturally coloured	1	The glass is pale green
Grozed edges	1	One grozed edge
Original quarry shapes	1	The quarry is shaped freehand around a depiction of a hand
Forming technique	0	There is no evidence of forming technique
Thickness	1	The quarry is relatively thick, 3.6 mm
Surface area		6
Decoration	1	R21 is painted with red-brown paint

Rievaulx C15c, 12 samples		
Feature	**No.**	**Description**
Weathering	12	The large group is in relatively un-corroded condition
Naturally coloured	12	Ten glasses are colourless and two are very pale green
Grozed edges	9	Nine glasses have one or two grozed edges
Original quarry shapes	5	Identifiable original shapes are freehand (R22), irregular (R41, R33), and sub-rectangular (R60, R61), which are undecorated border or glazier's strips
Forming technique	4	Four glasses have indents on the exterior sides showing broad production (R41, R43, R32, R33)
Thickness	12	The average thickness of the group is 1.8 mm
Surface area		164
Decoration	10	Two glasses are undecorated (R60, R61) and the remaining 10 are painted with red-brown or dark brown paint, three of which are silver stained (R32, R33, R37). Five glasses are stipple-shaded, these are the glasses depicting micro architecture (R33, R38, R43, R41) and one that is figurative (R22)

Rievaulx C15d, 4 samples		
Feature	**No.**	**Description**
Weathering		R40 and R48 are in good condition and R34 and R42 are devitrified in places
In-situ		R48 has a lead shadow
Naturally coloured		There are three colourless glasses
Coloured		There is one flashed red fragment
Grozed edges		R34, R40 and R42 have one or two grozed edges
Original quarry shapes		R48 is rectangular and probably a border piece
Forming technique		Indents on the exterior side of R40 is evidence of broad production
Thickness		As above, these glasses are thin, 1.9mm average
Surface area		67.25
Decoration		The three colourless glasses depicting micro-architectural motifs (R34, R40 and R42) are painted in red-brown paint. They are similar to five stipple shaded glasses in C15C and are probably part of the same glazing scheme. Two of these glasses are silver stained (R34, R42). R48 is in brown paint

APPENDIX 62 Technical analysis
WHITBY

Whitby C13a, 6 samples		
Feature	**No.**	**Description**
Weathering	6	All fragments in the group have a weathered crust and surface concretions. W9 has been consolidated with xxx resin.
In-situ	3	Two glasses are pitted on the exterior sides and two have lead shadows
Naturally coloured		The glassy core, which is visible in only a small area on each fragment is pale green
Coloured		There is one blue fragment (W27)
Grozed edges		Three fragments from the group retain at least one grozed edge
Original quarry shapes		W1 and W5 are rectangular border fragments, W1 is curved
Forming technique	0	There is no evidence of forming technique
Workshop practice		
Thickness		The samples are between 2.4-4.2 mm thick, the average is 3.1 mm
Surface area		119 cm^2
Decoration		W31 and W27 are plain, and the remaining four glasses are decorated with red-brown paint

Whitby C13b, 4 samples		
Feature	**No.**	**Description**
Weathering	4	All four glasses are very degraded: W2, W3, W10 have a continuous weathered crust extending over the edges. W10 has been consolidated with xxx resin
In-situ	1	W6 pitting on the exterior face
Naturally coloured	4	All glasses are pale green
Coloured	0	
Grozed edges	2	W2 and W6 have retained two grozed edges
Original quarry shapes	1	W6 is a long, rectangular border piece
Forming technique	0	There is no evidence of forming technique

Workshop practice	0	
Thickness	4	The samples are between 2.4 and 4mm thick, and the average is 3.2 mm
Surface area		46.5 cm^2
Decoration	4	All glasses are decorated with red-brown paint

Whitby C14a, 1 sample		
Feature	**No.**	**Description**
Weathering	1	W8 has patches of weathered crust
In-situ	1	The glass has a lead shadow on the exterior side
Naturally coloured	1	The glass is pale green
Grozed edges	1	There are two grozed edges
Original quarry shapes	1	W8 is a triangular or diamond-shaped quarry although the apex is absent
Forming technique	0	There is no indication of forming technique
Workshop practice	0	
Thickness	1	W8 is 2.4 mm thick
Surface area		18 cm^2
Decoration	1	The glass is painted in a red-brown paint, which has bubbled in places

Whitby C14b, 4 samples		
Feature	**No.**	**Description**
Weathering	4	W11 is severely corroded with a crust that has flaked away at the edges. It has been consolidated with xx resin. Conversely, W15 is in good condition showing only localised areas of corrosion and oxide staining. W25 and W26 are severely corroded with a weathered crust that is flaking in places. The surface of W26 is rough
Naturally coloured	2	W11 and W15 are naturally coloured pale green glasses
Coloured	2	W25 and W26 are striated red glasses and are probably from the same sheet based on appearance
Grozed edges	2	W15 and W25 have retained one grozed edge

Original quarry shapes	0	No original shapes are present
Forming technique	0	There is no evidence to suggest forming technique
Workshop practice		
Thickness	4	W15 and W11are 3 and 3.8 mm thick, W25 and W26 are 2 mm and 2.5 mm
Surface area		33.75 cm^2
Decoration	2	W11 has decoration in red-brown paint and W15 is painted dark brown/black. The red glasses are plain

Whitby C14c, 1 sample		
Feature	**No.**	**Description**
Weathering	1	W7 has a dulled surface with localised areas of corrosion and concretions
Naturally coloured	1	Pale green
Grozed edges	1	It retains three grozed edges
Original quarry shapes	1	The original shape is rectangular, possibly a border fragment
Forming technique	0	There is no evidence to suggest forming technique
Workshop practice		
Thickness	1	It is 2.5mm thick
Surface area		14 cm^2
Decoration	1	The glass has red-brown painted decoration

Whitby C14d, 4 samples		
Feature	**No.**	**Description**
Weathering	4	All silver-stained fragments are in good condition (W13, W14, W16), and the blue sample (W28) is severely corroded and iridescent
In-situ		
Naturally coloured	3	Pale green
Coloured	1	W28 is blue
Grozed edges	3	Three glasses have one grozed edge

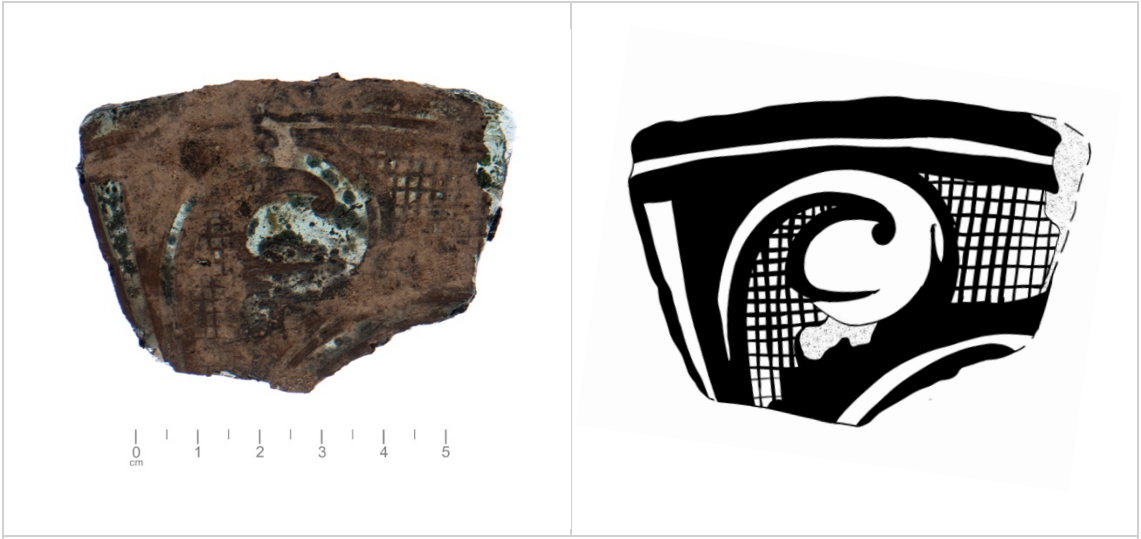
Original quarry shapes	0	There are no original quarry shapes present
Forming technique	0	W18 contains short, thin bubbles although forming technique cannot be determined
Workshop practice		W18 is repaired with shellac
Thickness	4	All samples are relatively thin, averaging 2.1 mm
Surface area		15 cm^2
Decoration	3	W13, W14, W16 are decorated with dark brown/ black paint and are silver stained. W28 is plain

Whitby C15a, 4 samples		
Feature	**No.**	**Description**
Weathering	4	All glasses are un-corroded
Naturally coloured	4	Four glasses are pale green
Coloured	0	
Grozed edges	3	Three glasses have retained between one and four grozed edges
Original quarry shapes	1	W16 is an apex of a lozenge shape
Forming technique	0	Long, thin bubbles seen in W13 are evidence of broad production however, there is no evidence of how the remaining samples were formed.
Workshop practice		W20 is repaired with shellac
Thickness	6	The glasses are between 1.0-2.5 mm in thickness, averaging 2.1 mm
Surface area		24.25 cm^2
Decoration	4	All four are painted in dark brown paint. W13, W14 are silver-stained

Whitby C15b 2 samples		
Feature	**No.**	**Description**
Weathering	2	W21 is un-corroded and W24 is contaminated with gypsum - in-situ
Coloured	2	Flashed red
Grozed edges	0	
Original quarry shapes	0	
Forming technique	0	

Workshop practice	0	
Thickness	2	W21 is 2.5 mm thick and W24 is 4 mm thick
Surface area	2	6.50
Decoration	0	Both red glasses are plain

Whitby C15c, 3 samples		
Feature	**No.**	**Description**
Weathering	3	W33 and W30 have weathered crusts, and W22 has a few localised spots of oxide staining W30 has gypsum
Naturally coloured	3	All glasses are pale green
Grozed edges	1	W22 has one grozed edge
Original quarry shapes	0	No original quarry shapes are apparent
Forming technique	0	W22 contains round bubbles of various sizes, although the method of forming is indeterminate
Workshop practice		
Thickness	3	Average thickness is 2.1 mm
Surface area		21.75 cm^2
Decoration	1	W22 is stipple shaded using brown paint, W30 and W33 are plain



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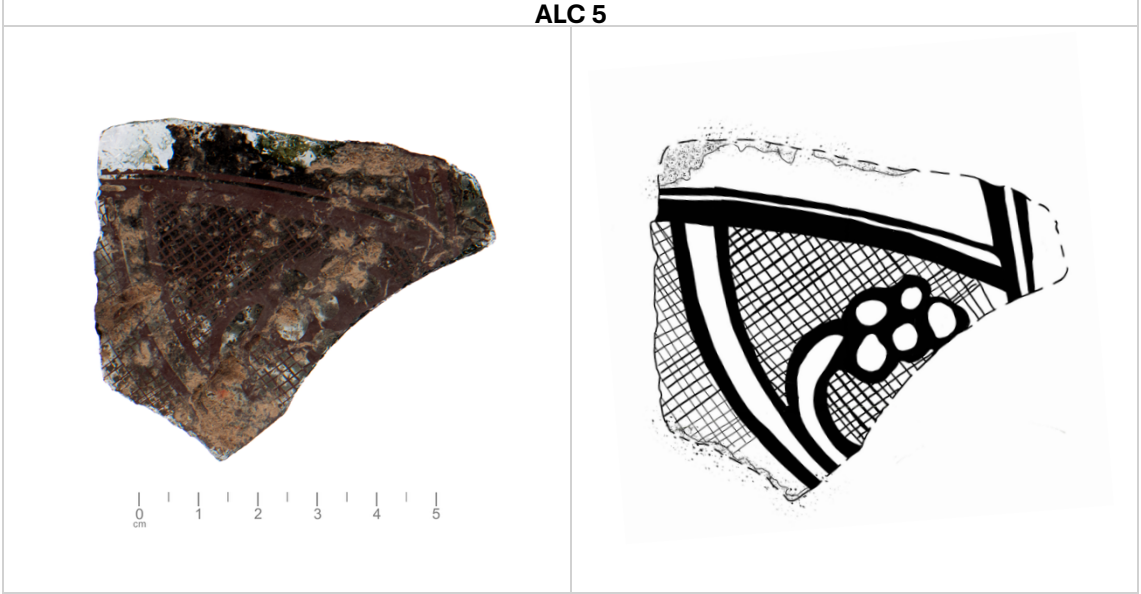

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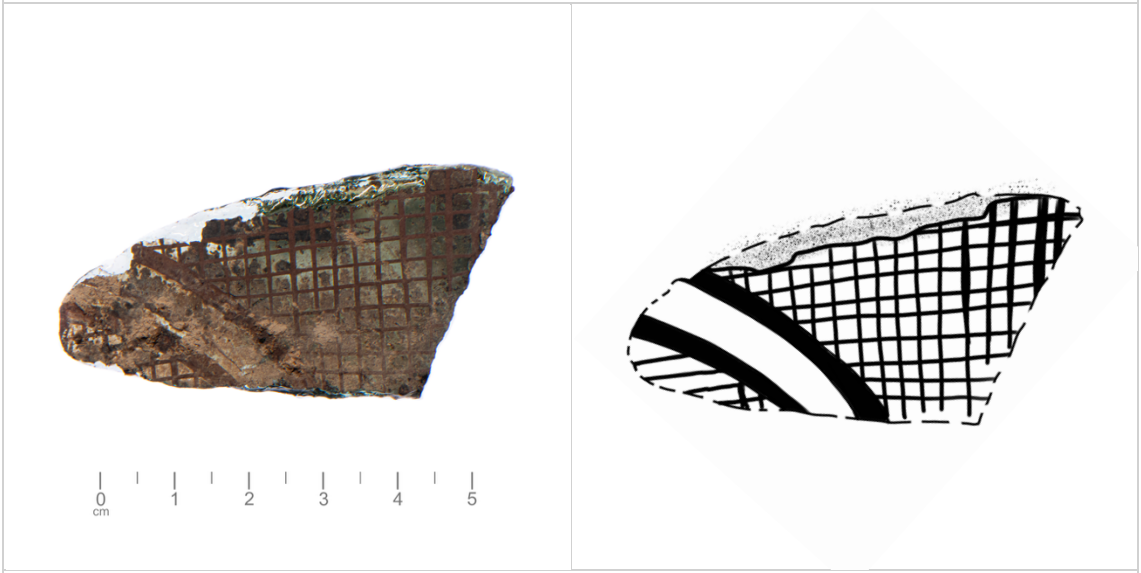

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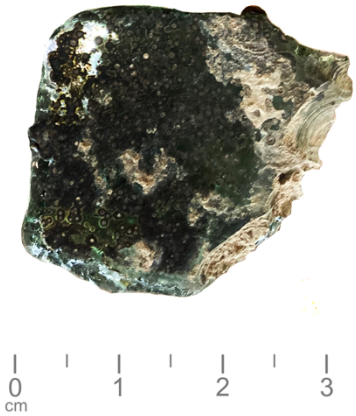

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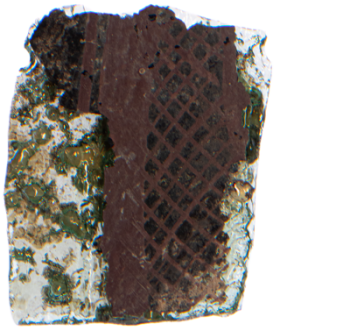

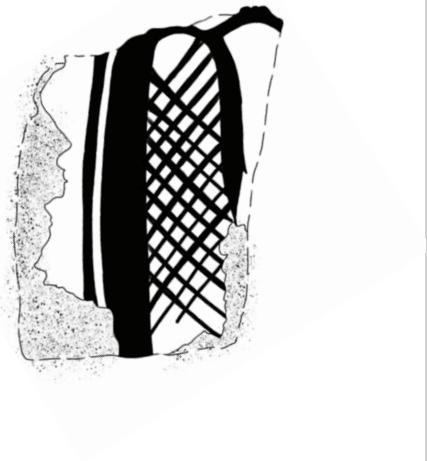

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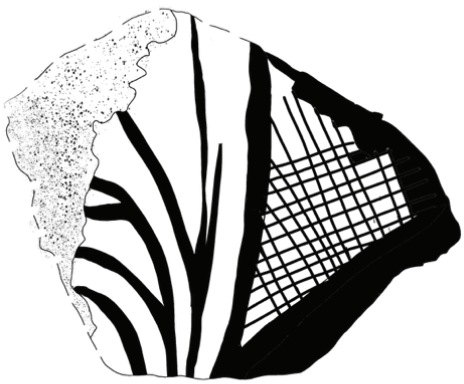

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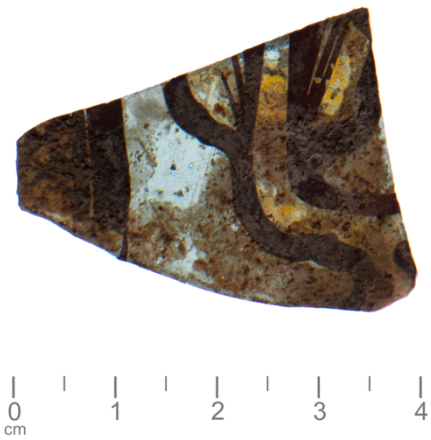

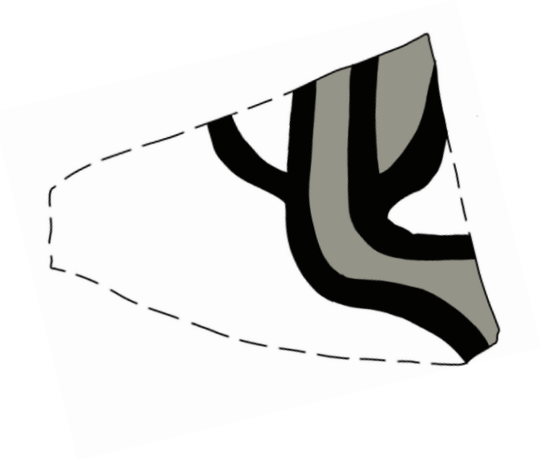

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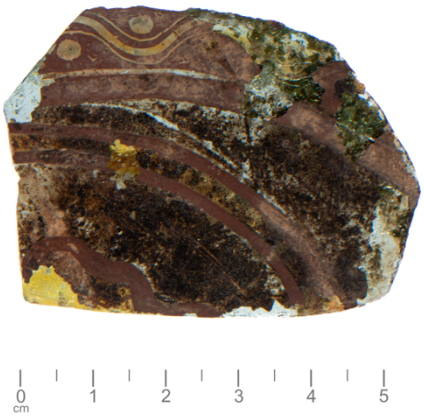

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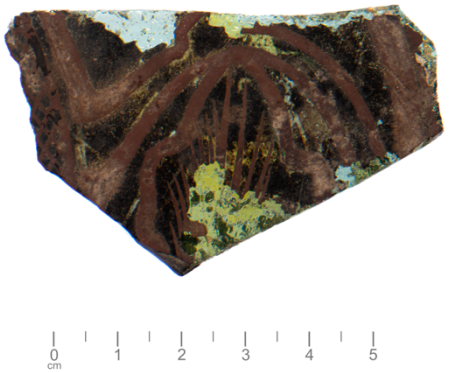

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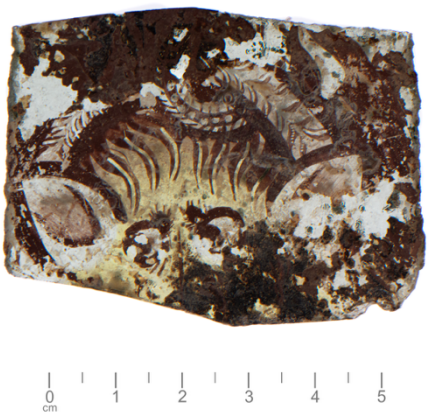

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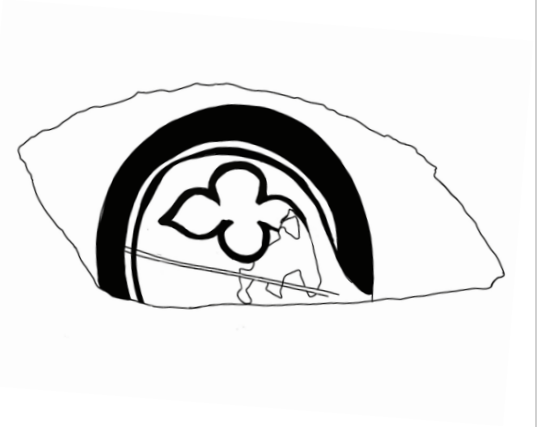
ALC 43

ALC 44

ALC 46

ALC 47

ALC 49



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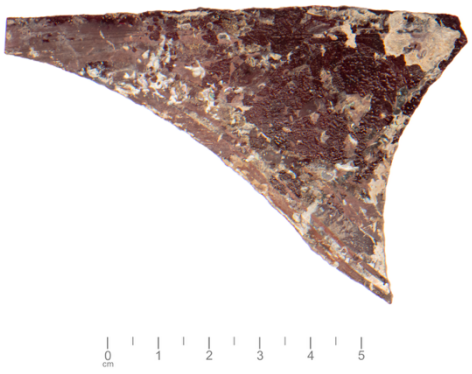
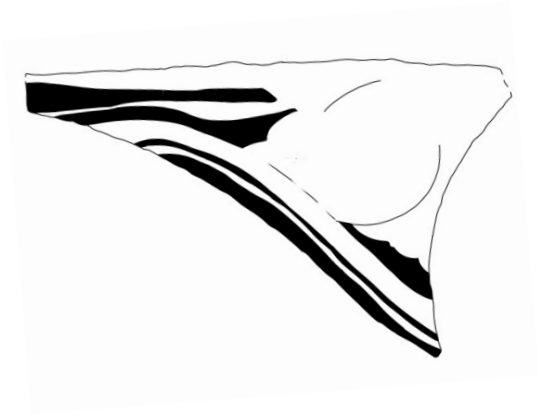
ALC 57b

ALC 60





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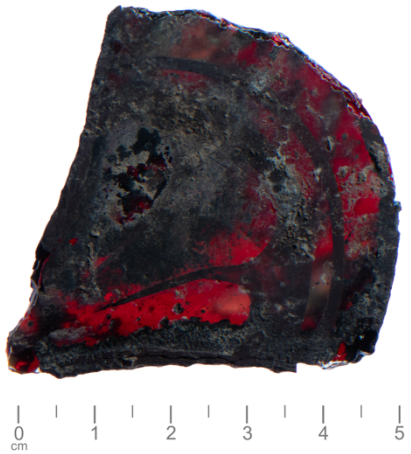

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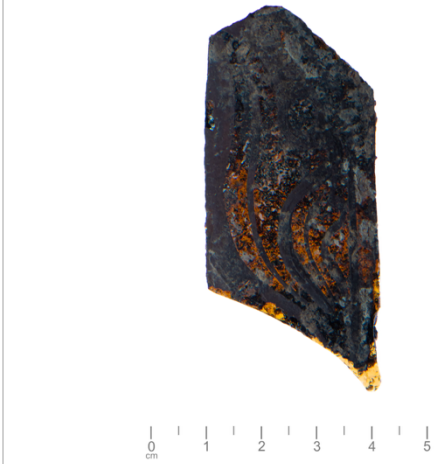

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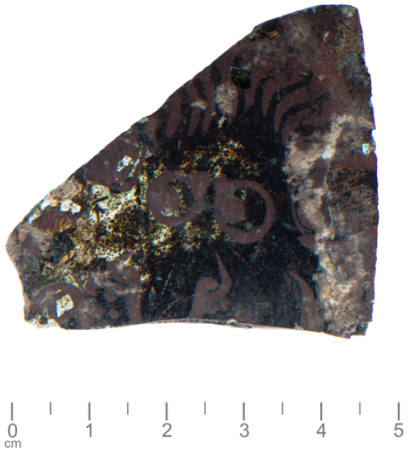

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ALC 75

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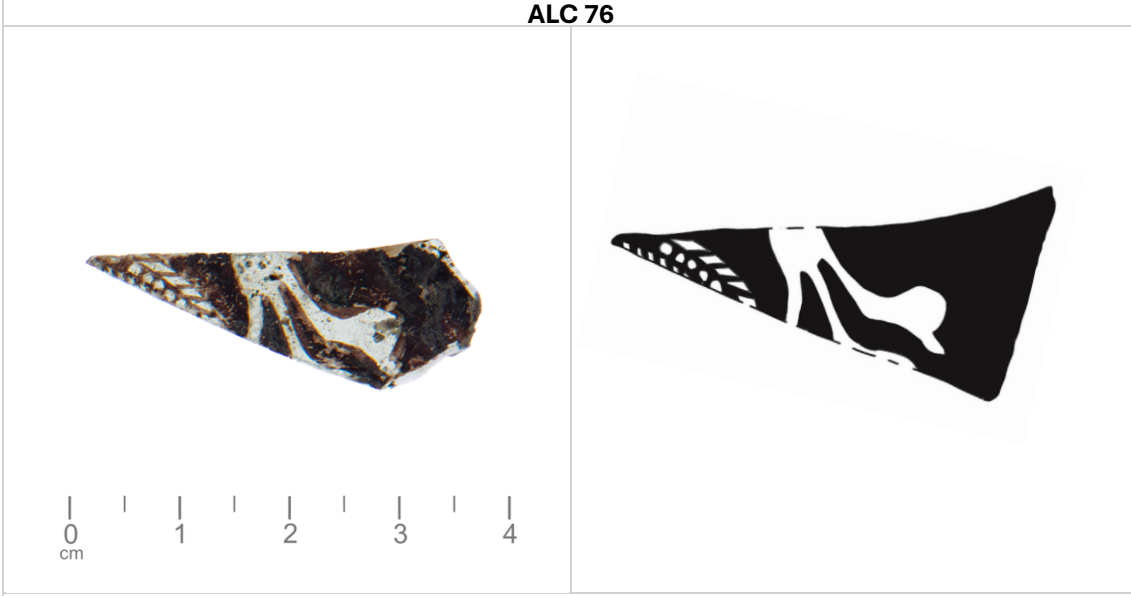

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ALC 80

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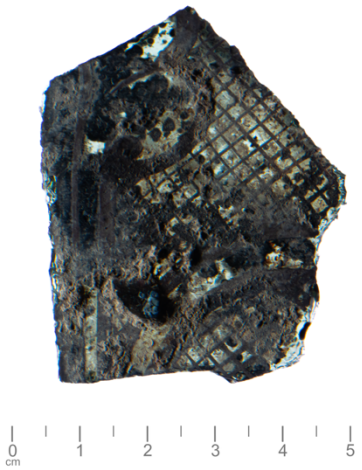

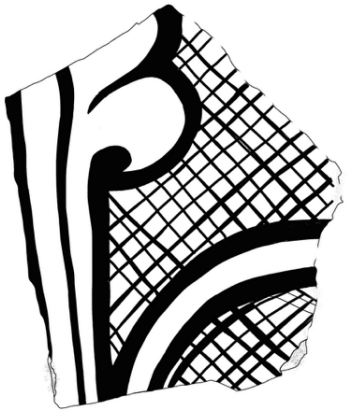

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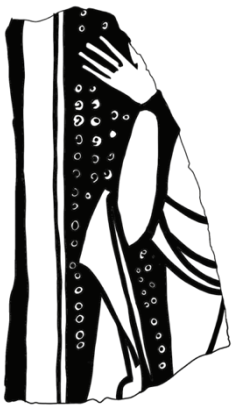

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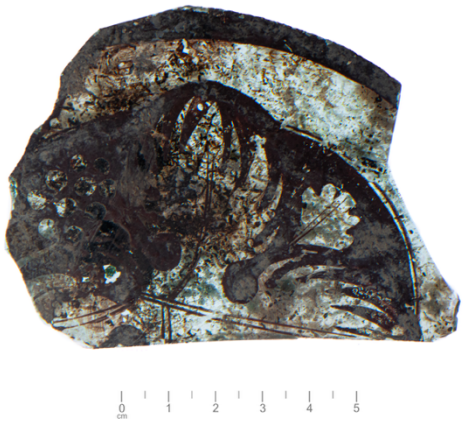

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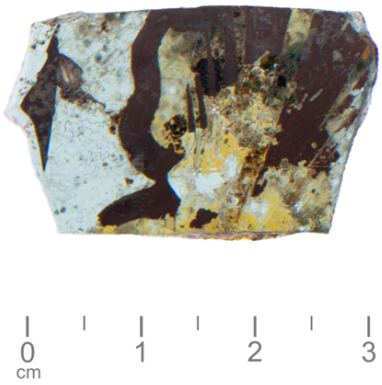

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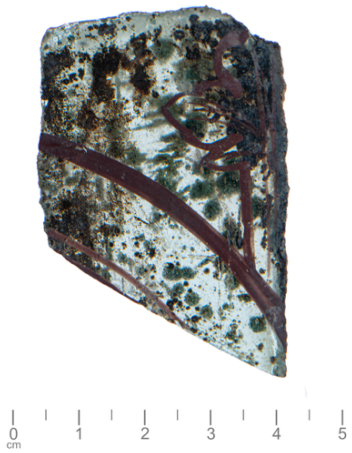

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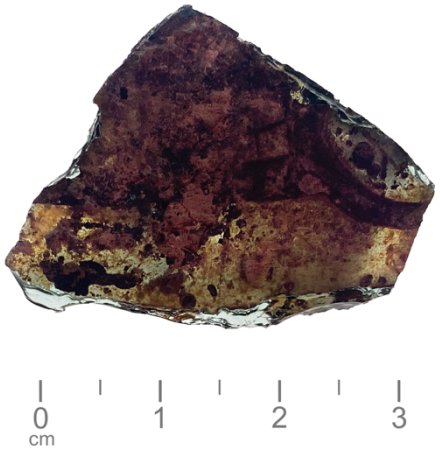
ALC 51

ALC 742



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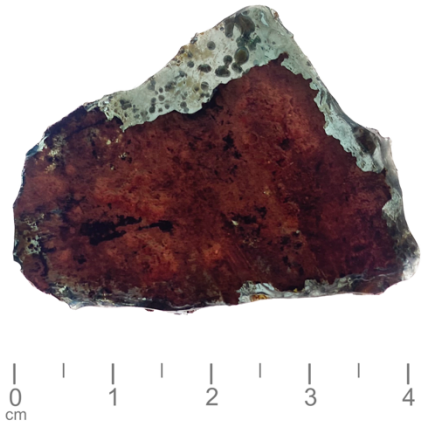

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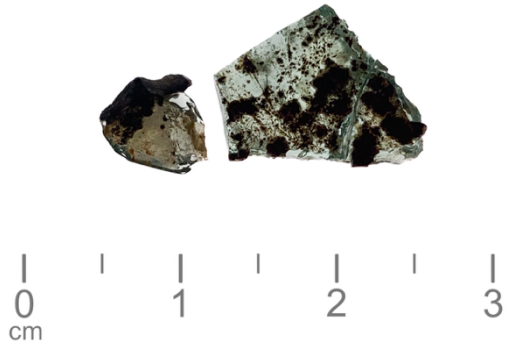

ALC 898

APPENDIX 64 BARDNEY

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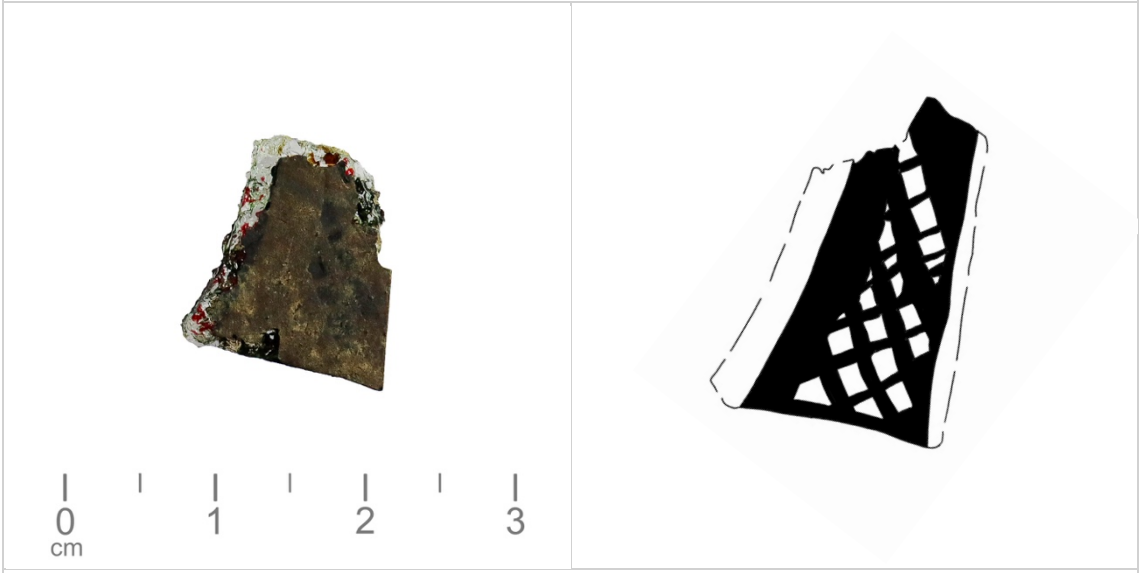
BA2



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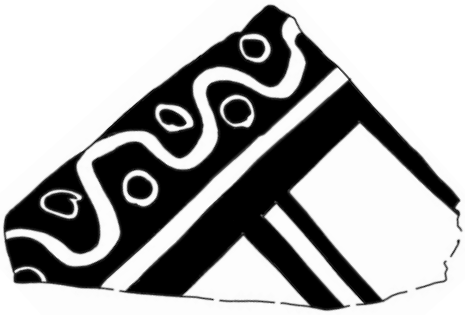

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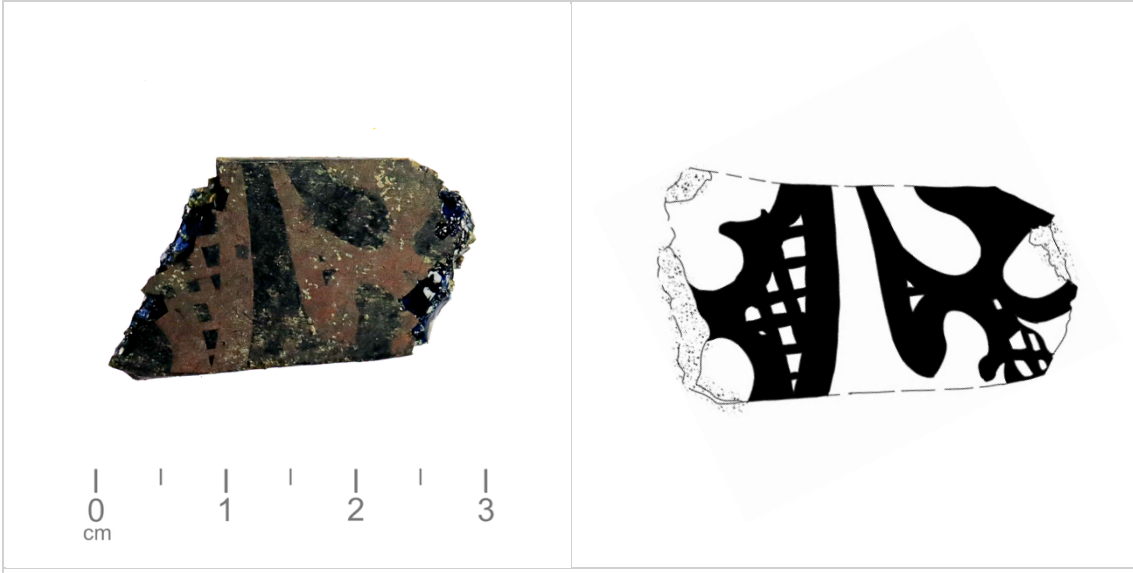

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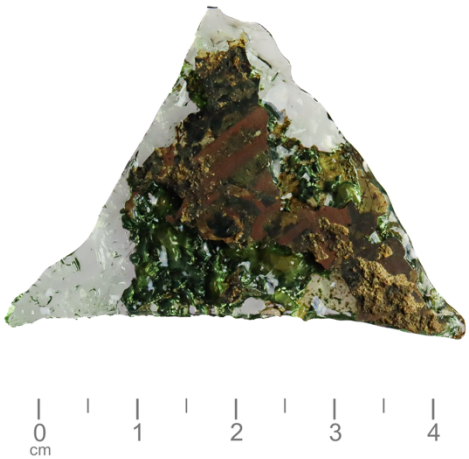

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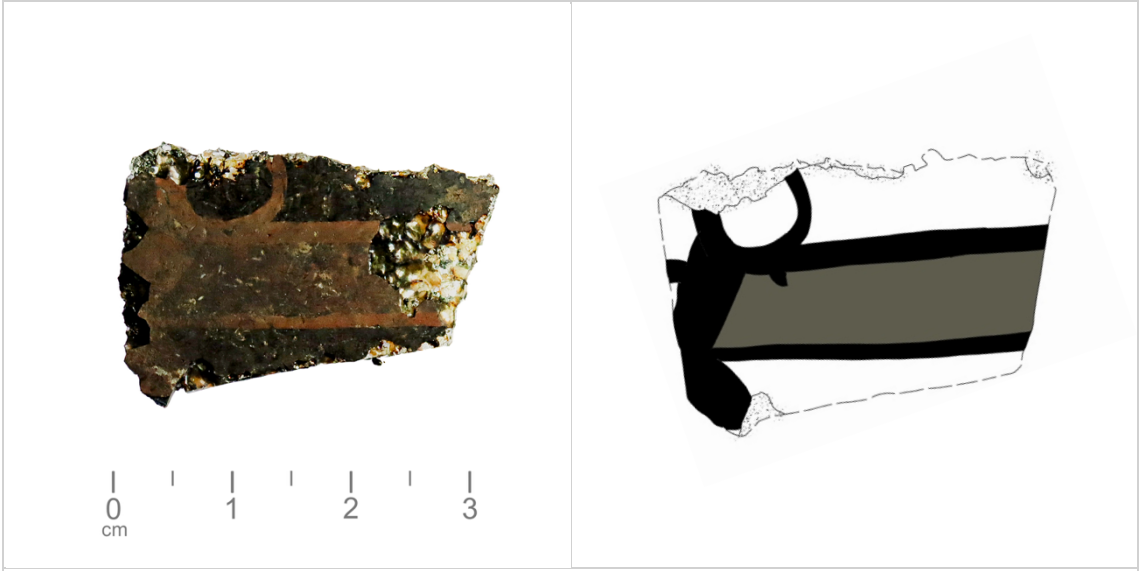

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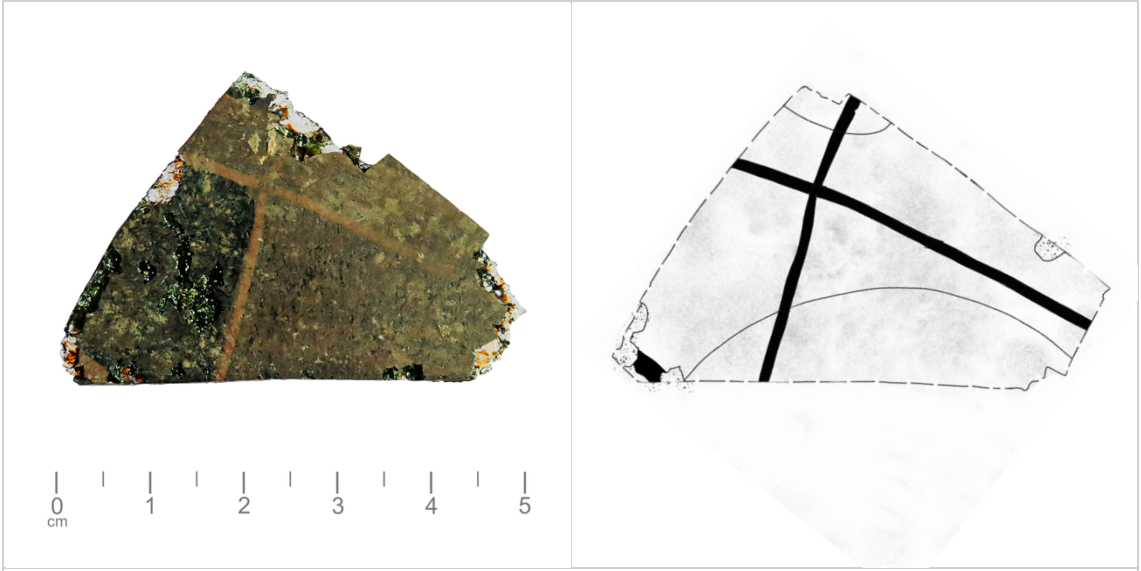

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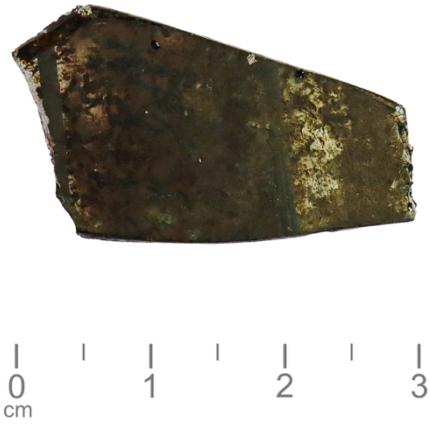

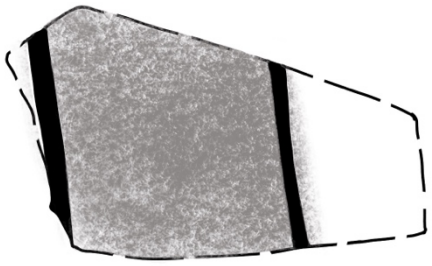

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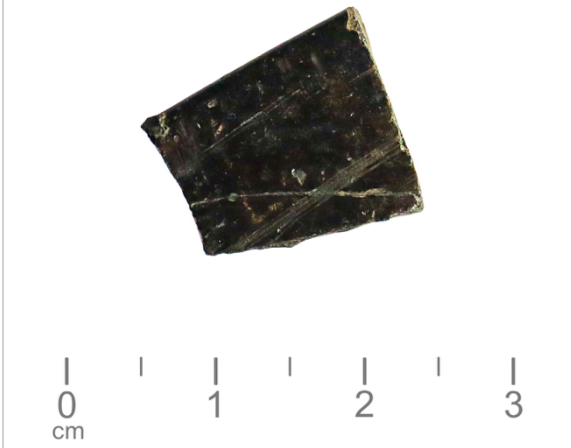

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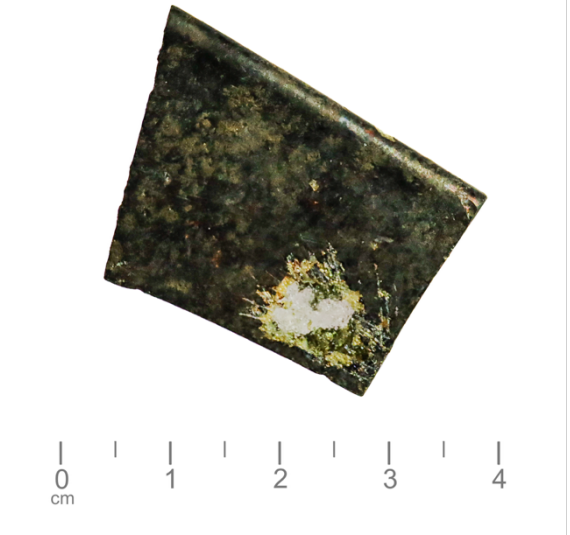

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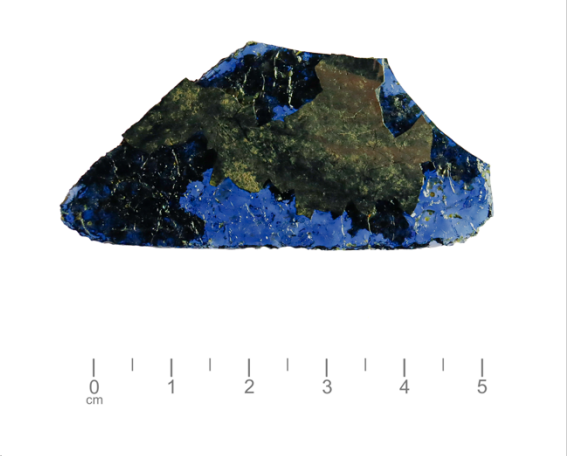
BA22

BA22 BACK

BA23



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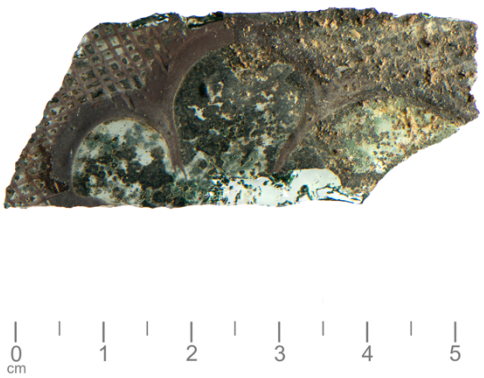

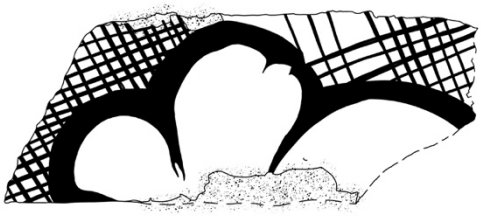

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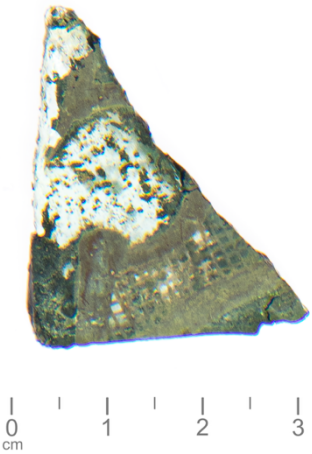

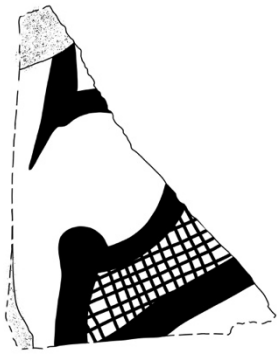

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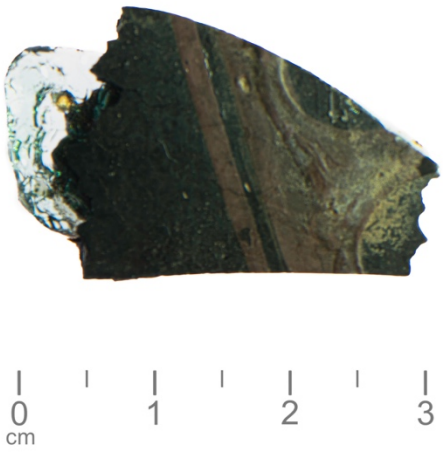

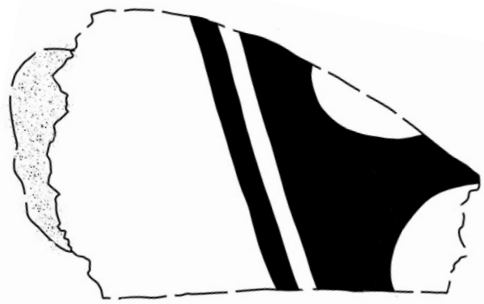

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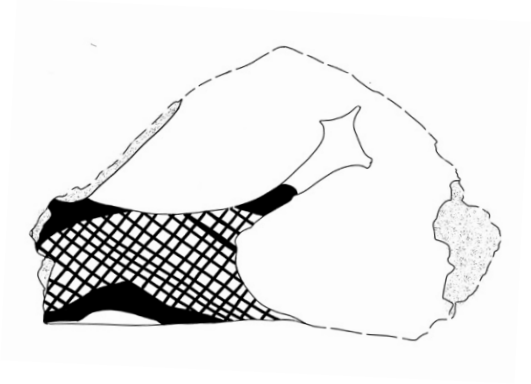

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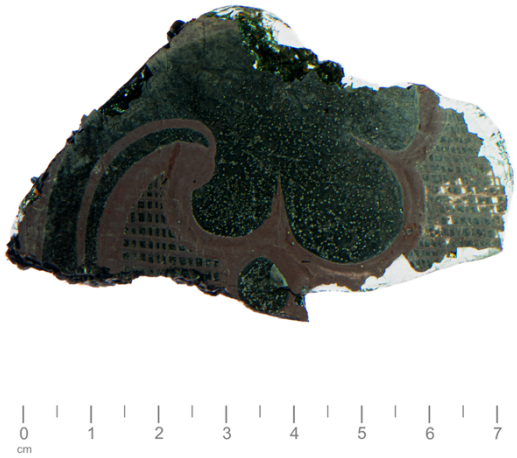

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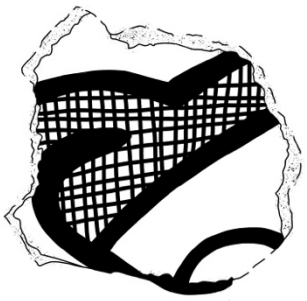

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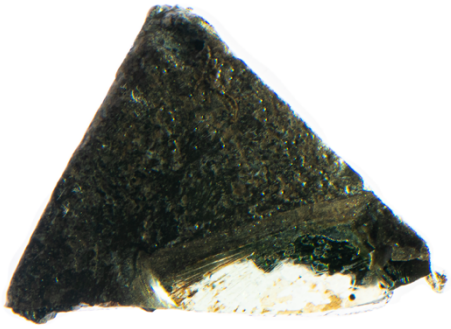

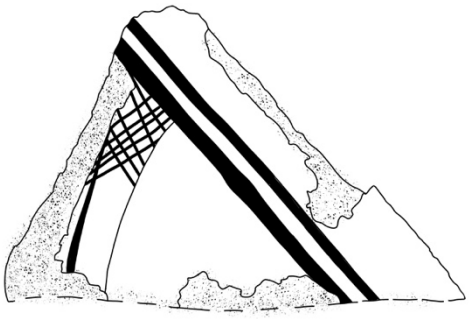

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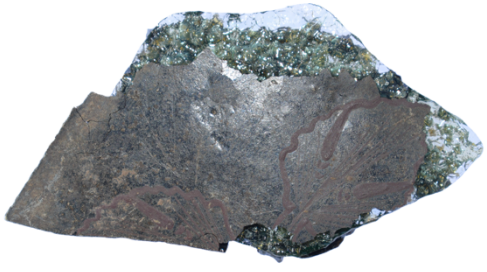

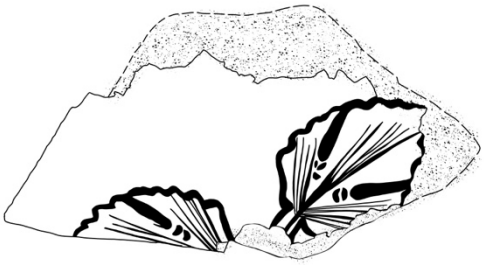

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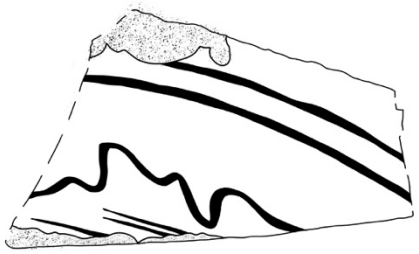

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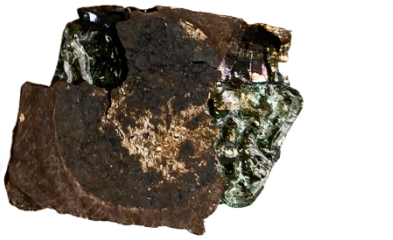

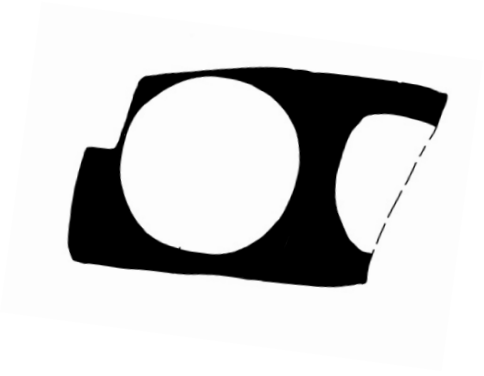

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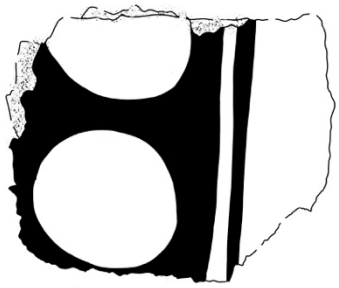

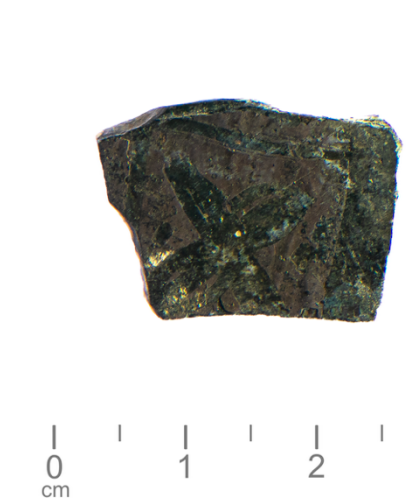

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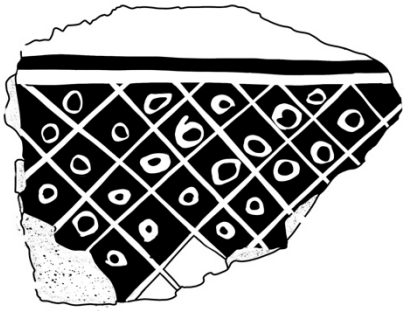

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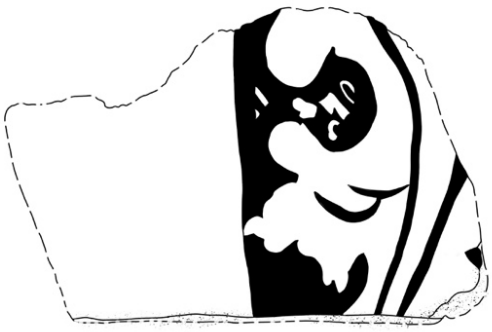

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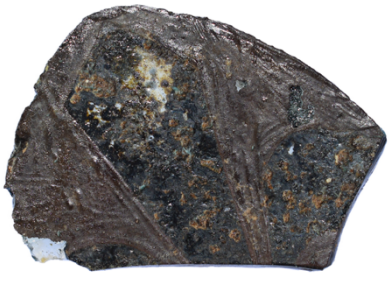

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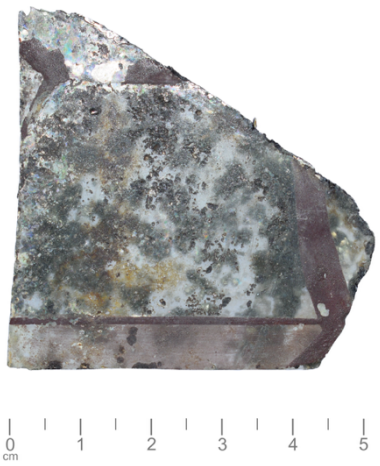

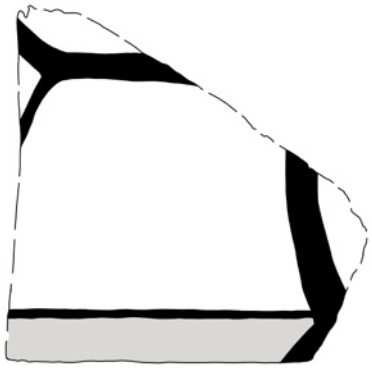

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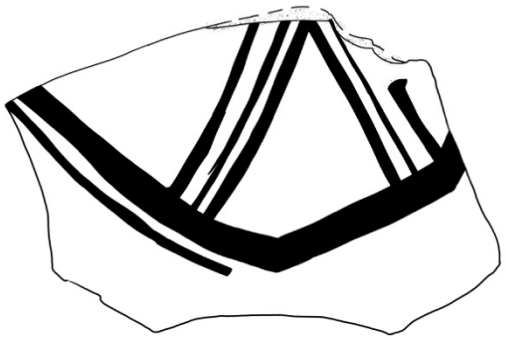

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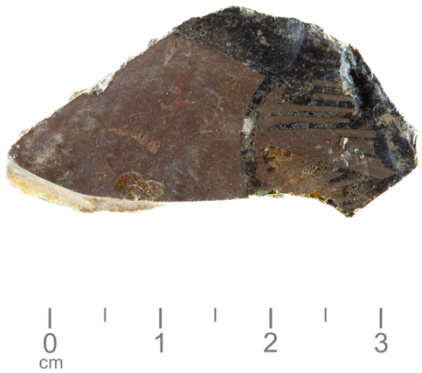

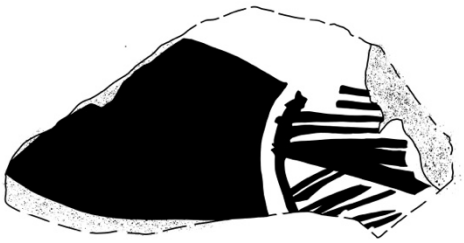

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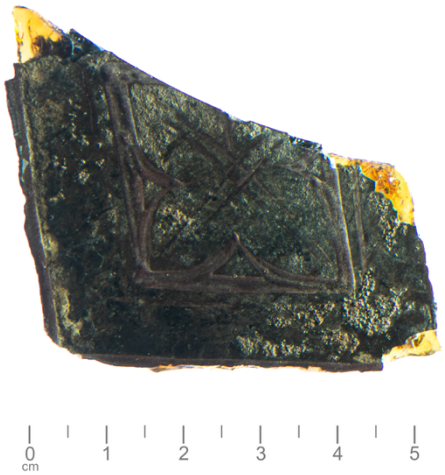

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Too degraded to photograph	
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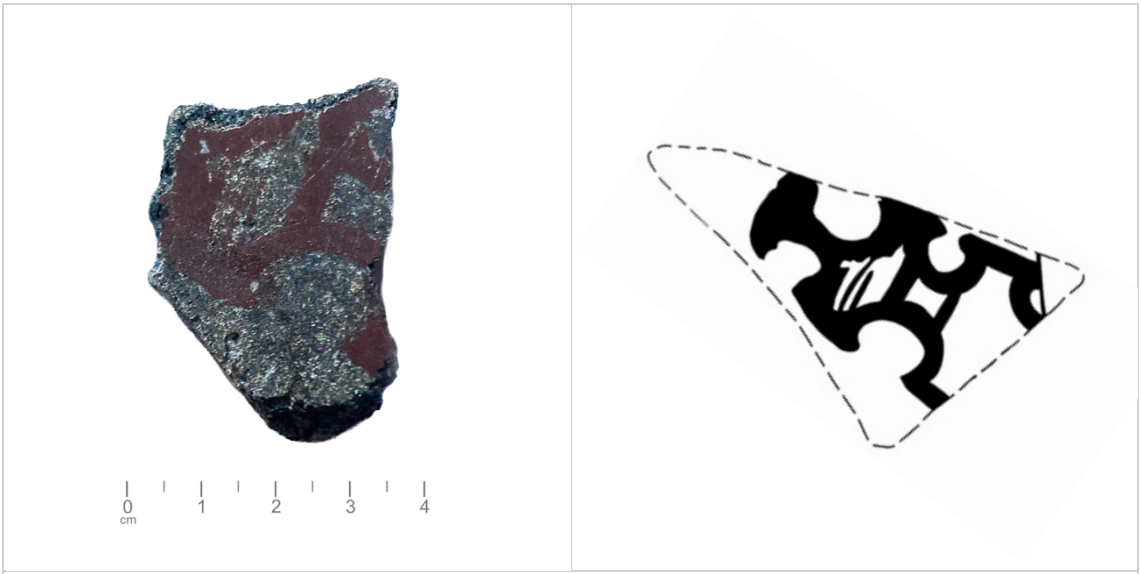
B47	



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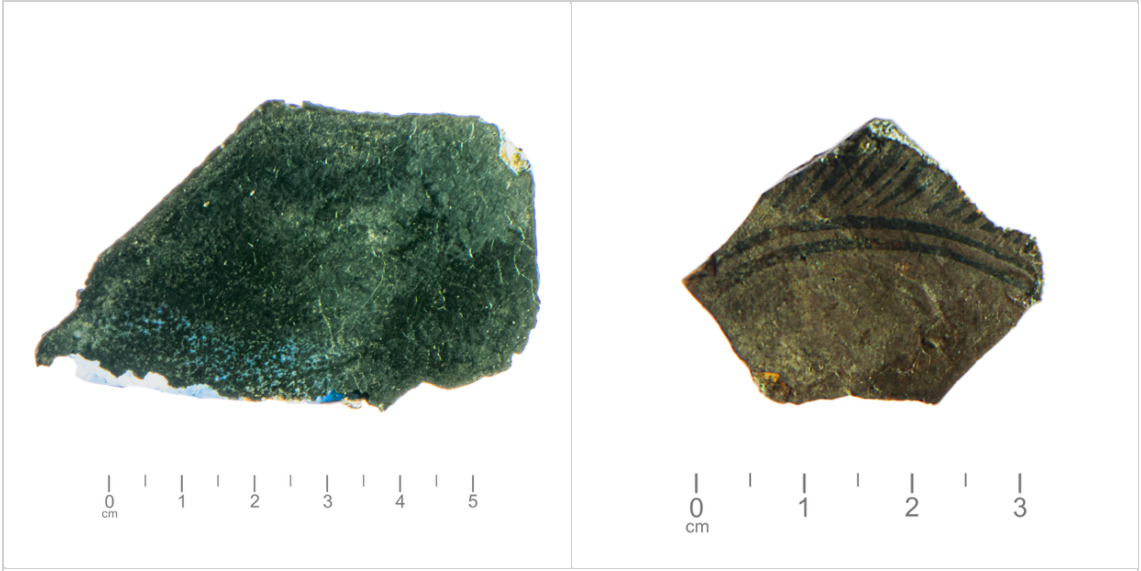

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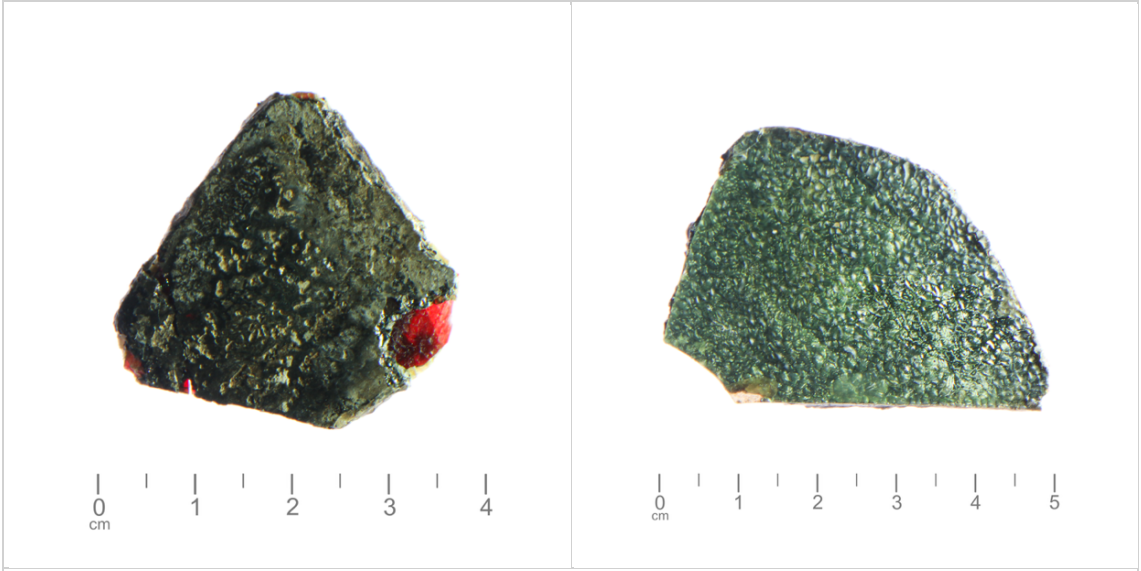

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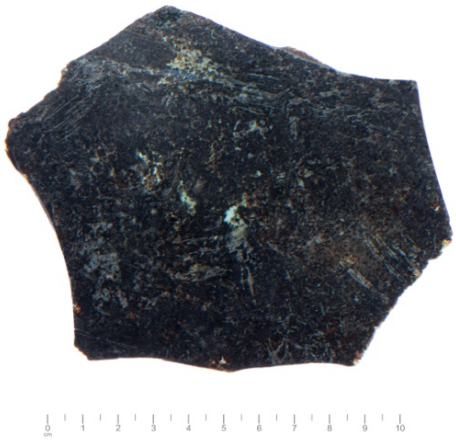	
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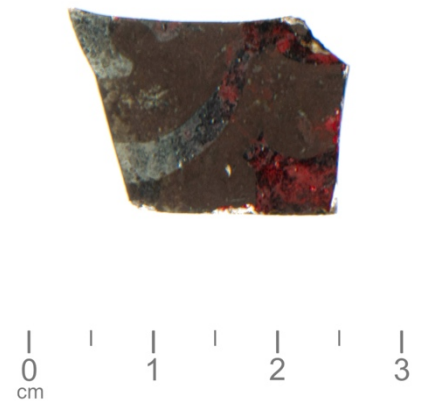

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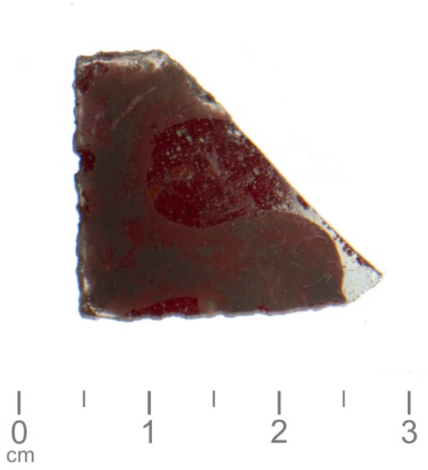

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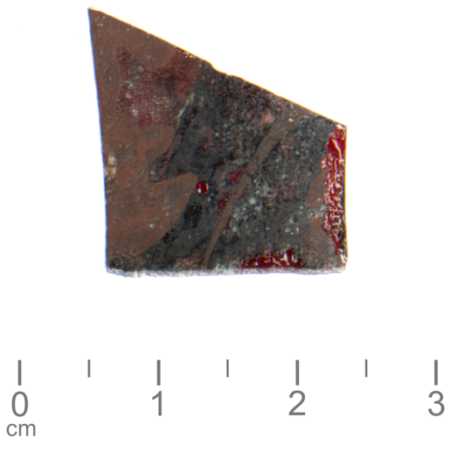

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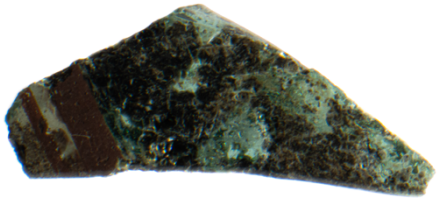

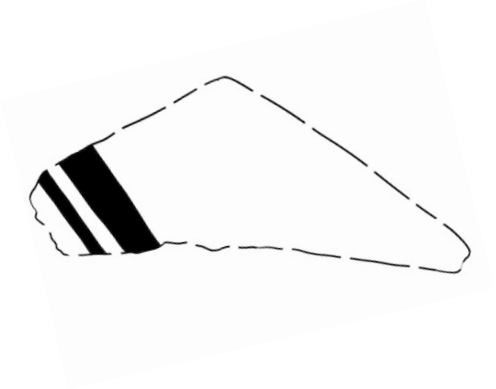

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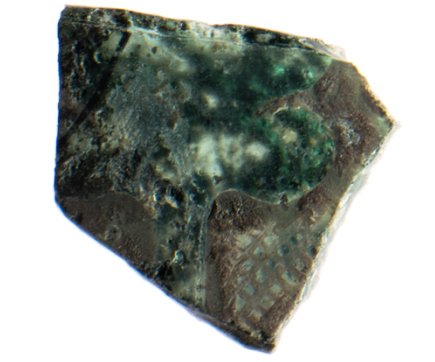

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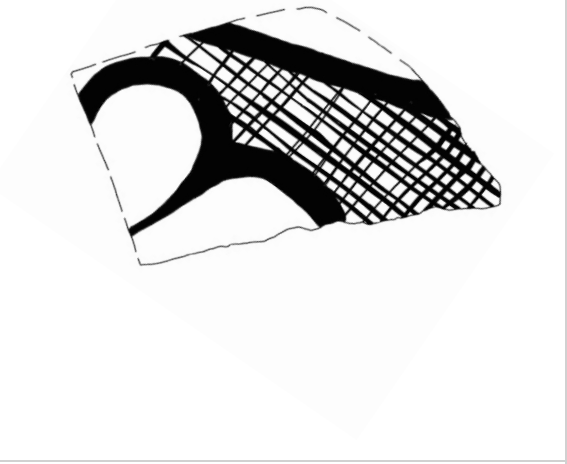

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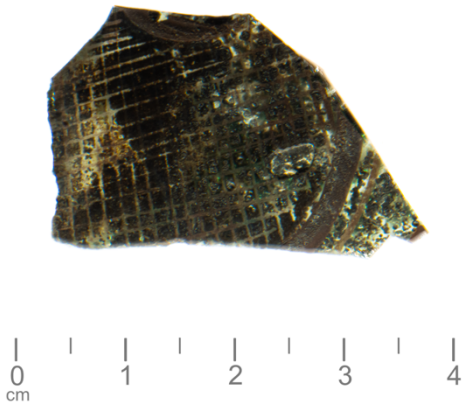

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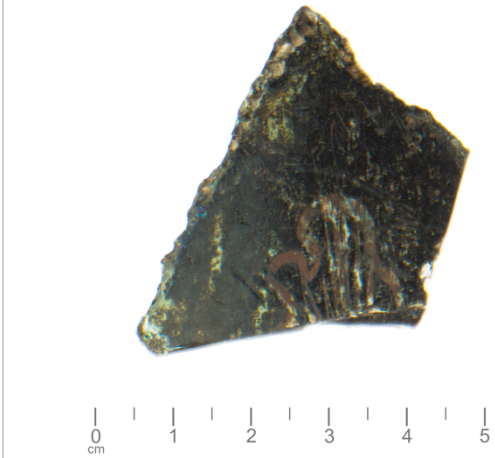

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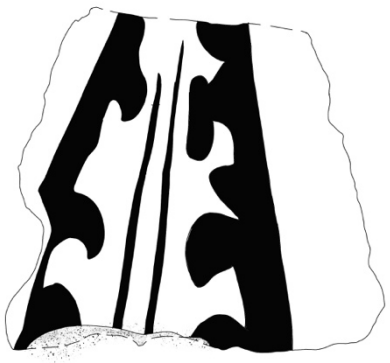

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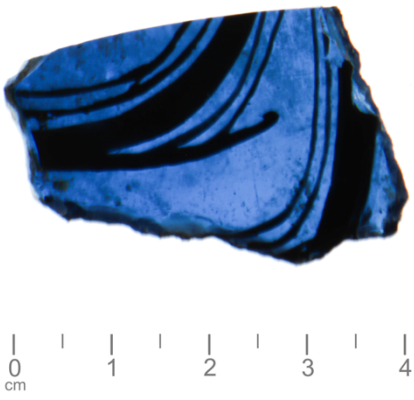

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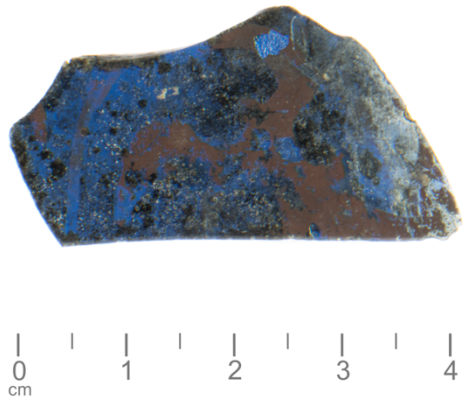

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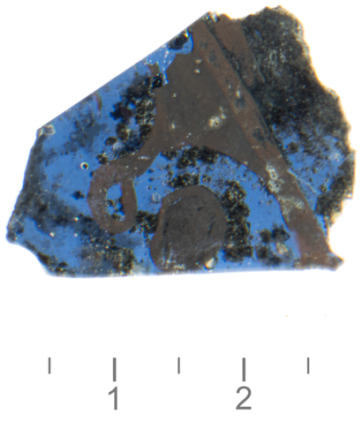

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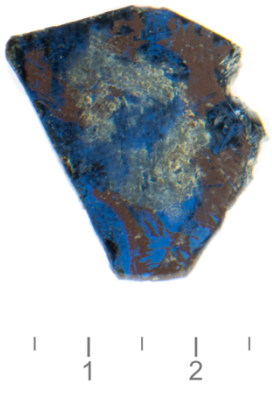

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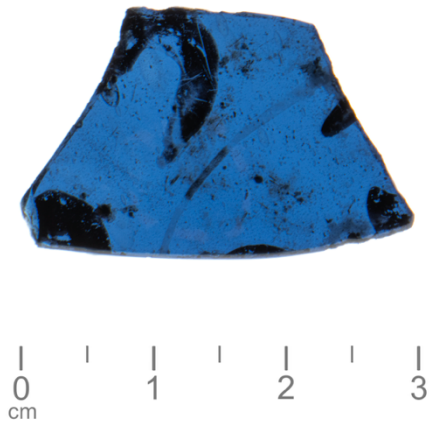

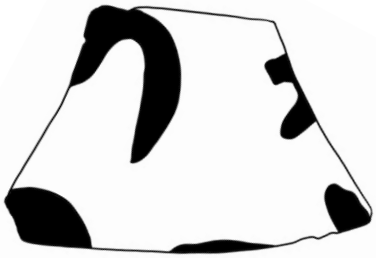

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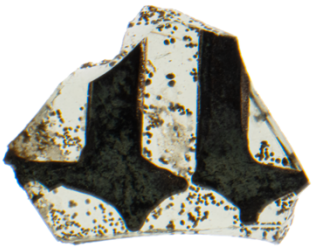

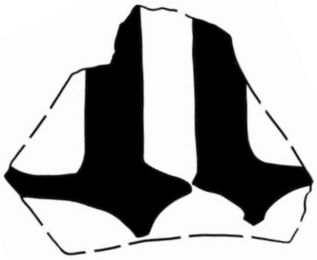

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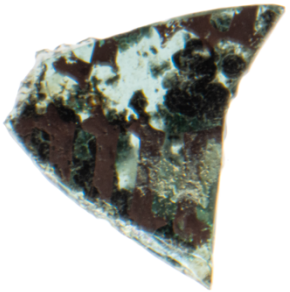

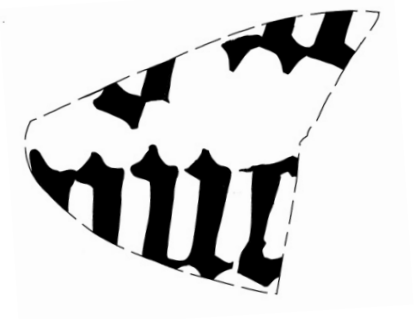

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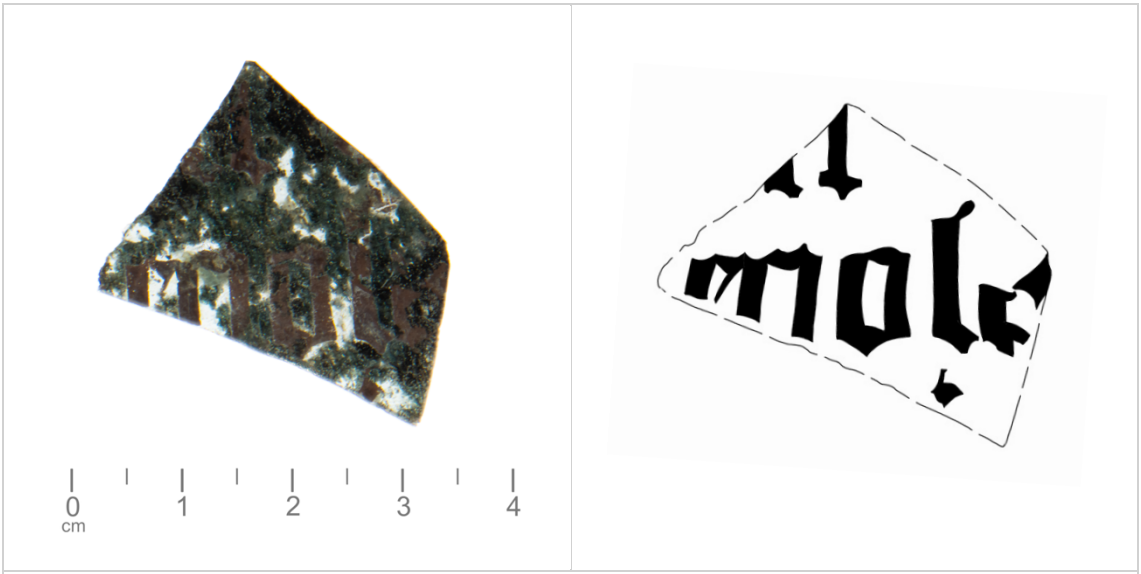

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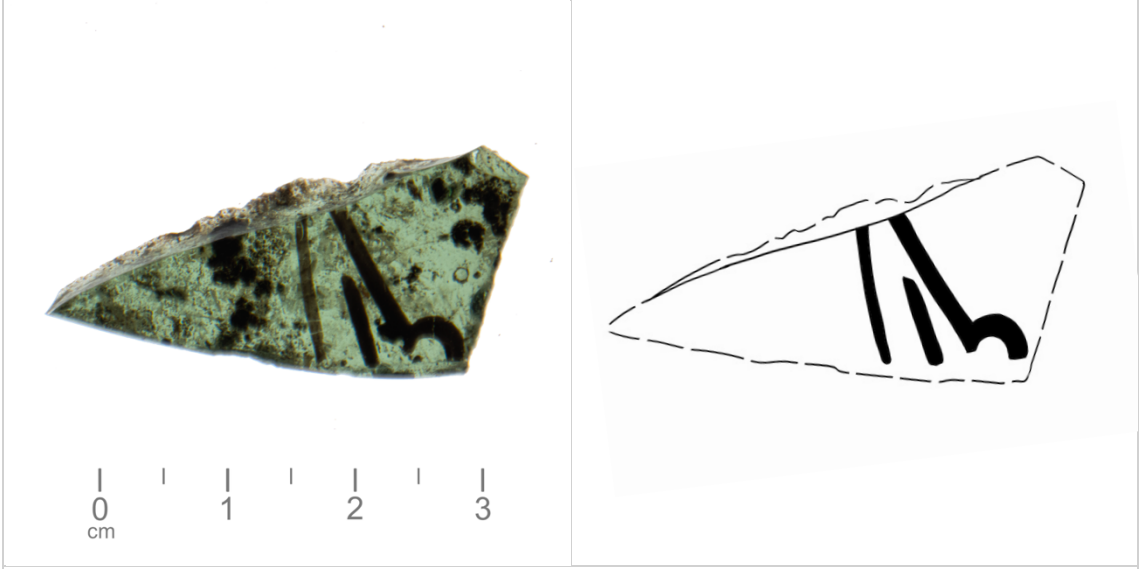

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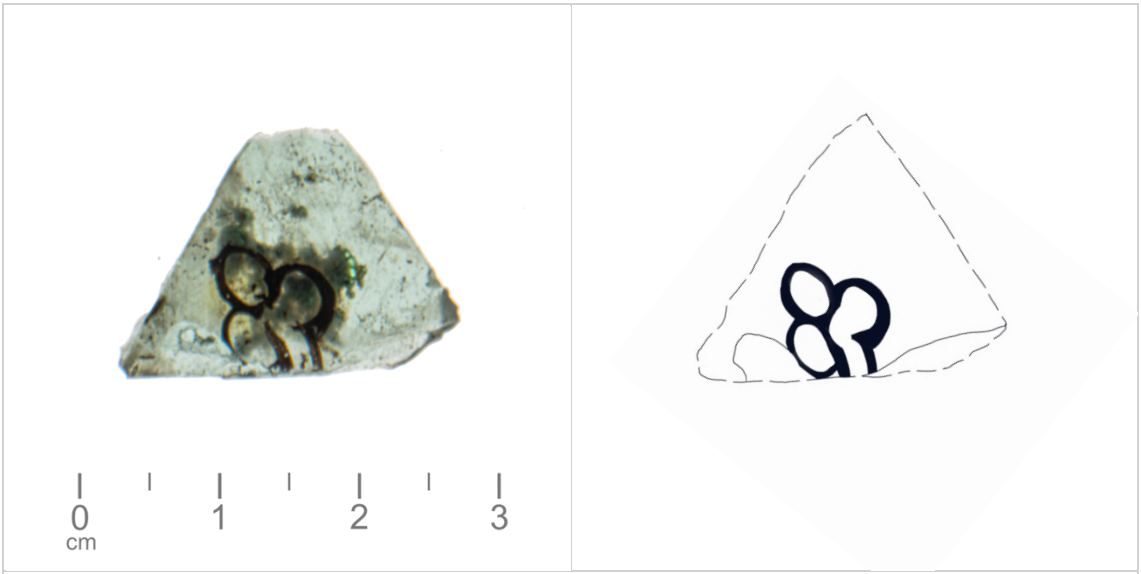

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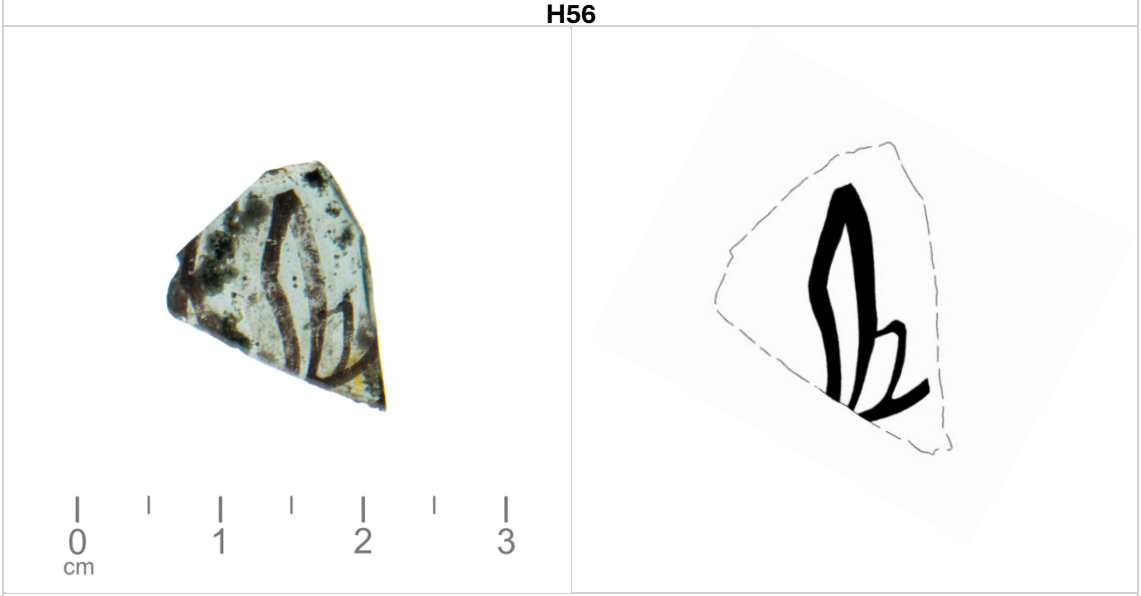

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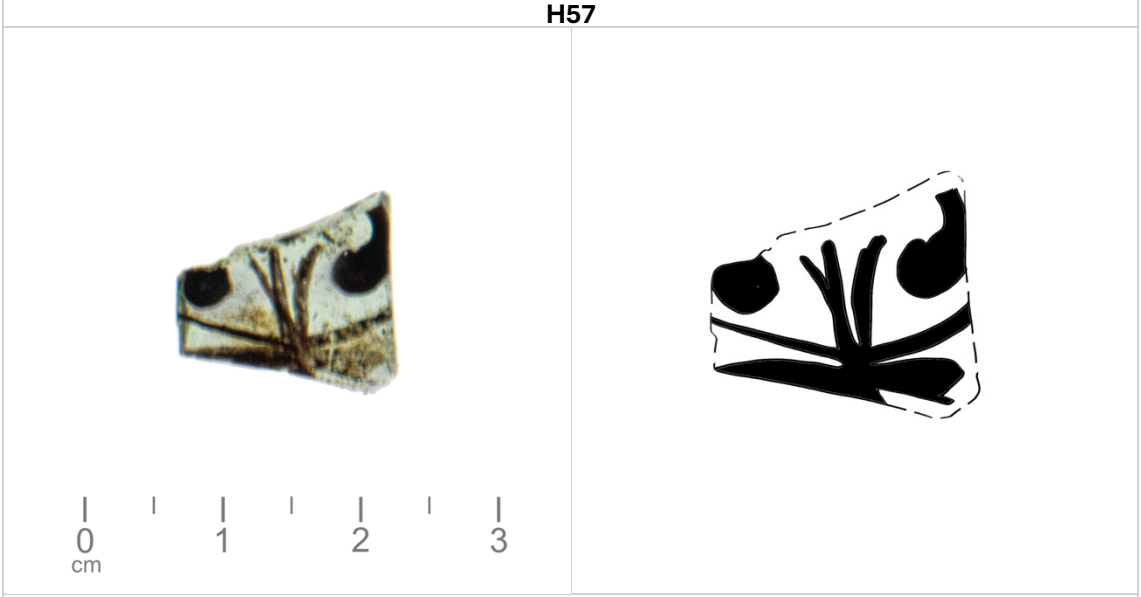

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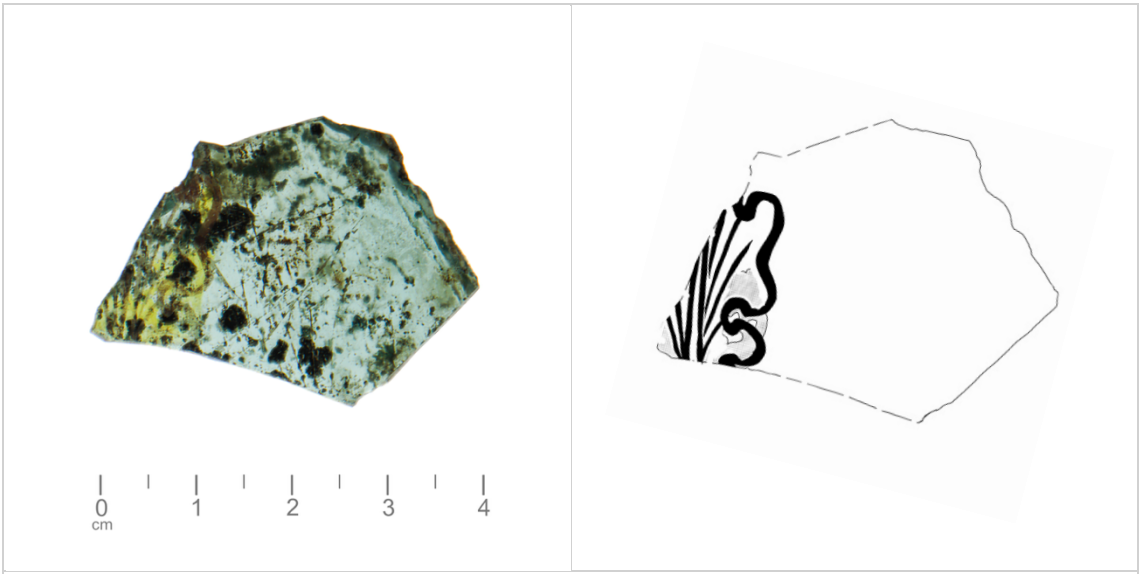

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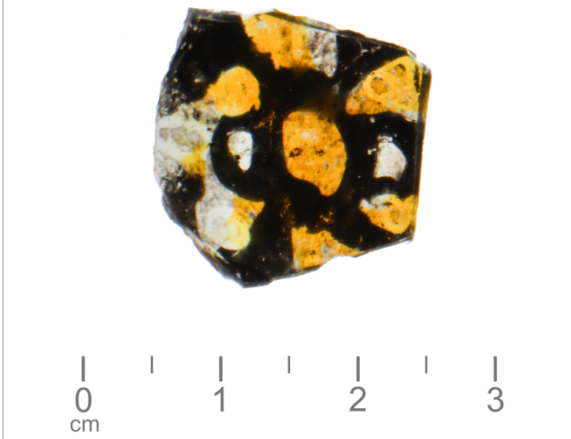

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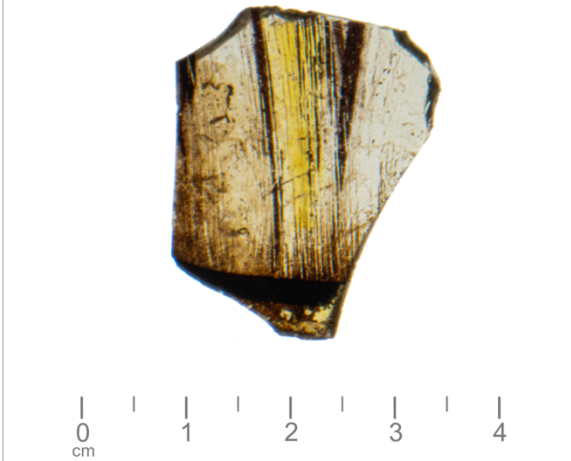

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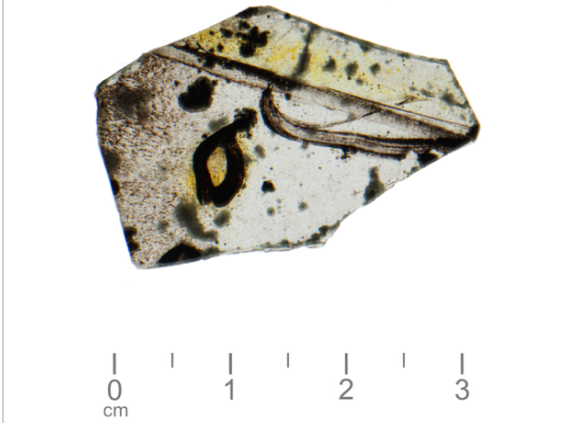

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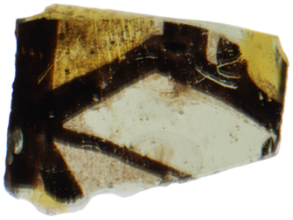

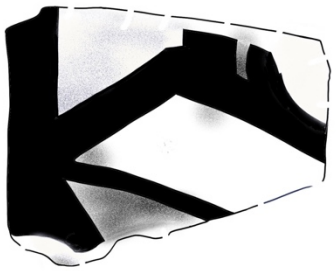

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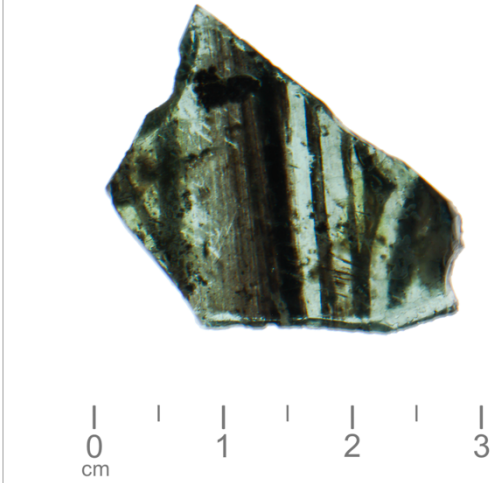

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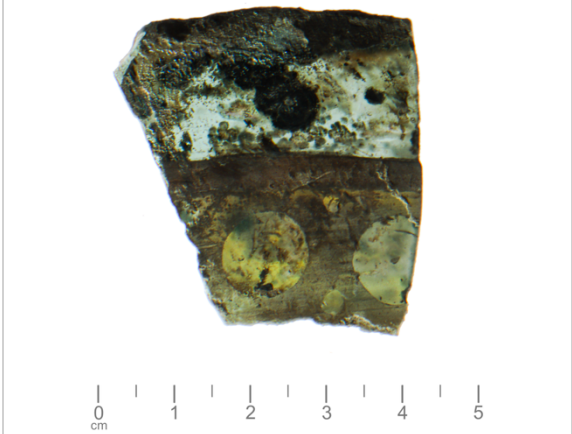

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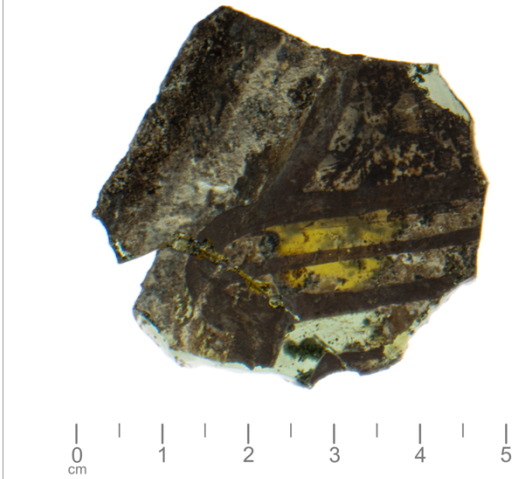

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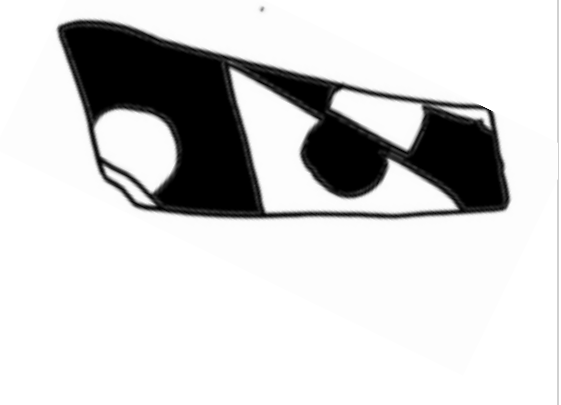

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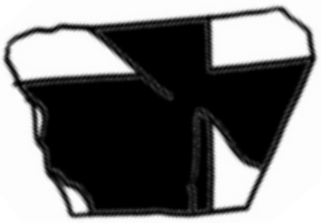

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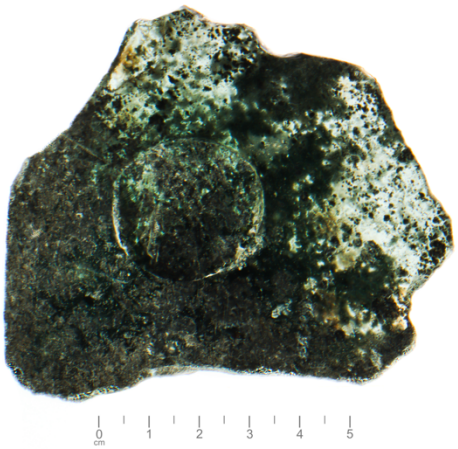

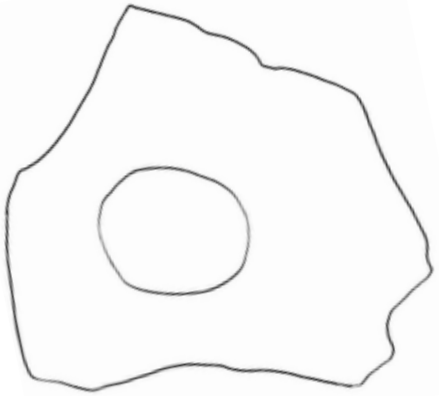

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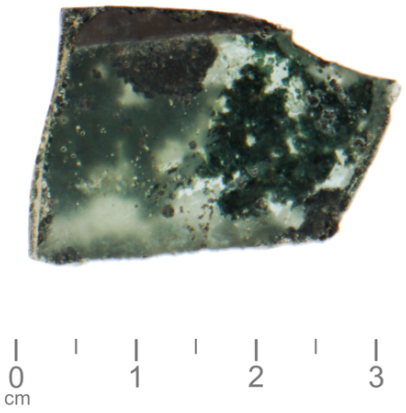

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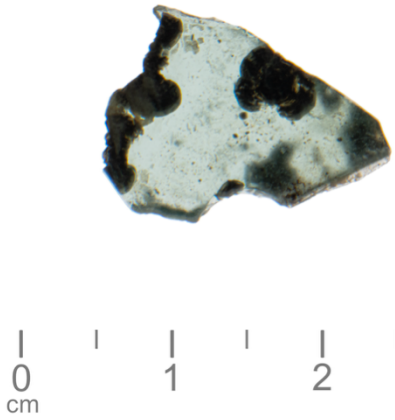

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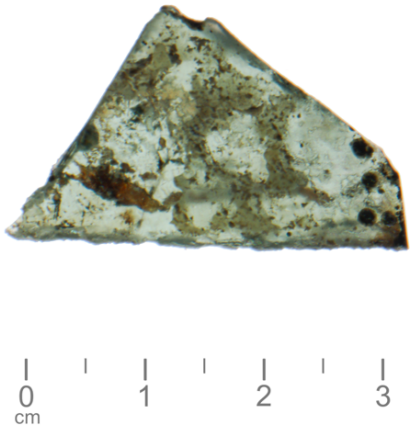

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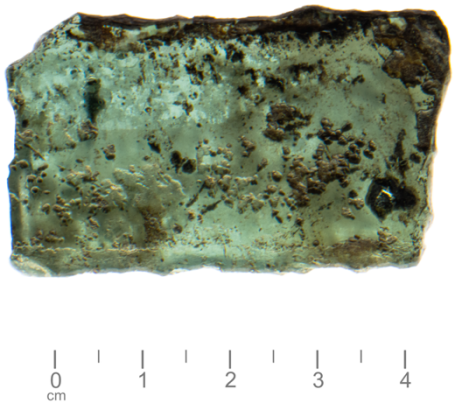

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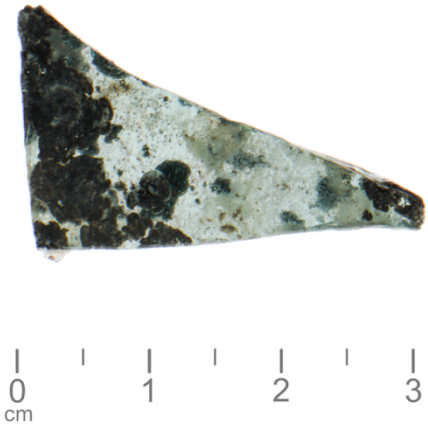

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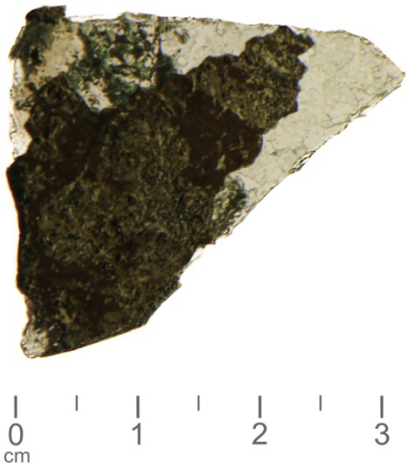

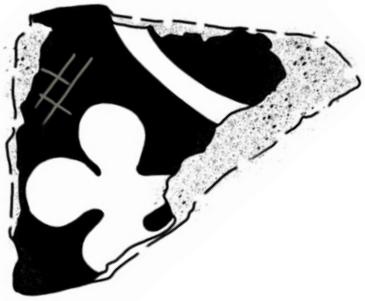

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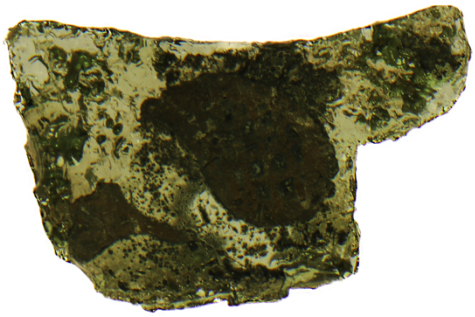

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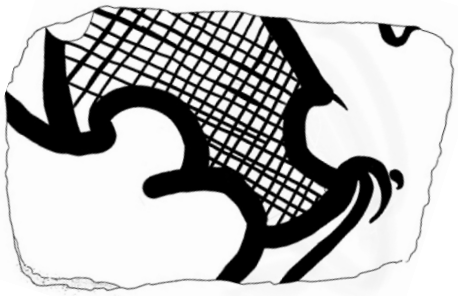

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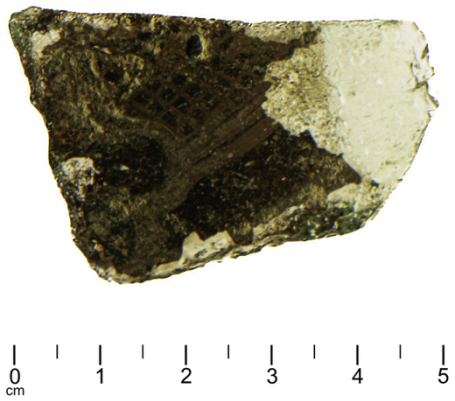

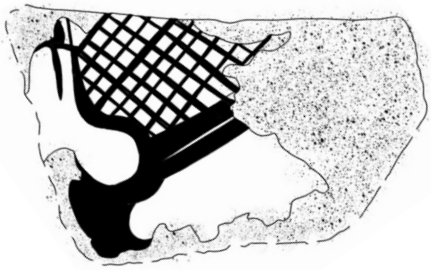

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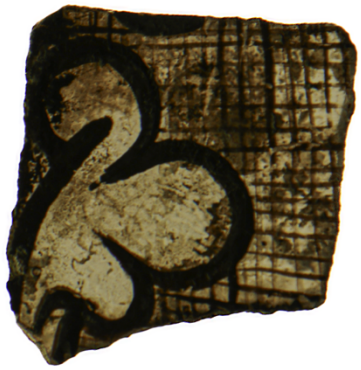

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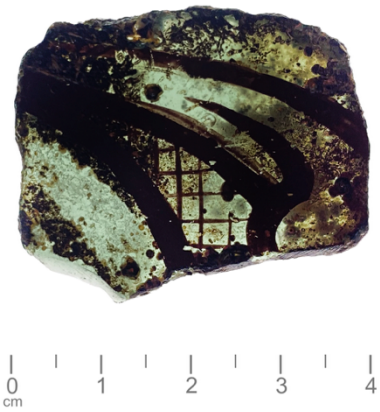

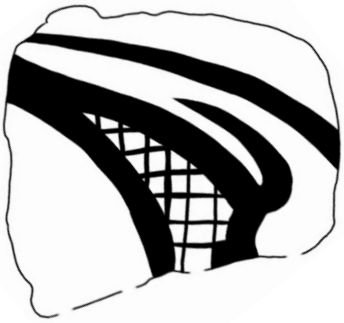

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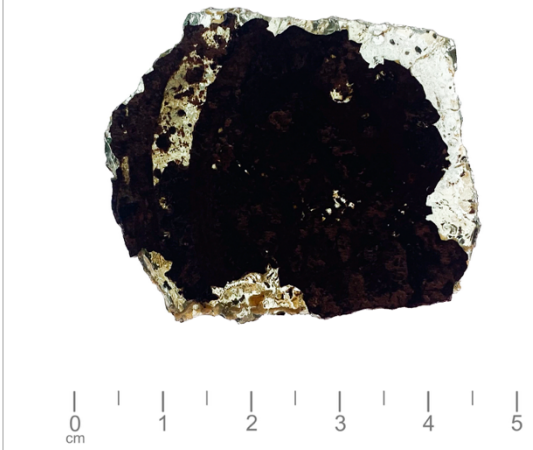

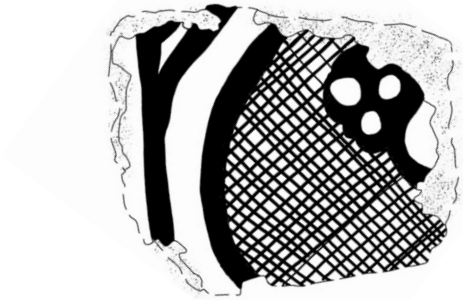

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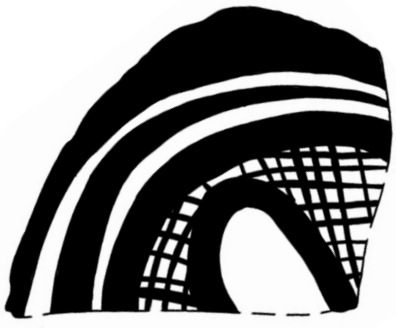

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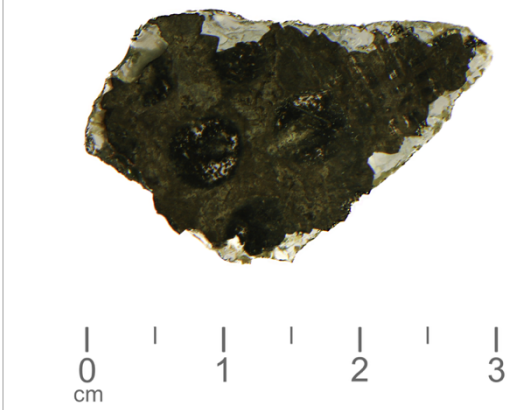

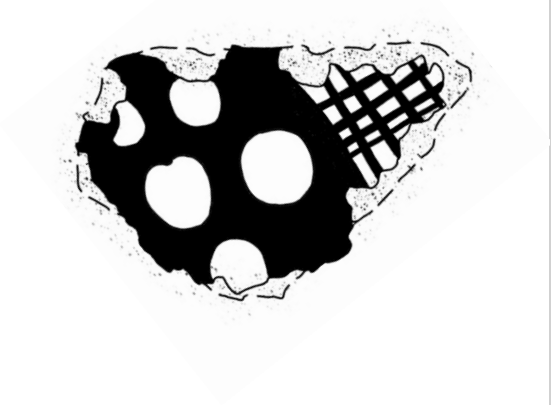

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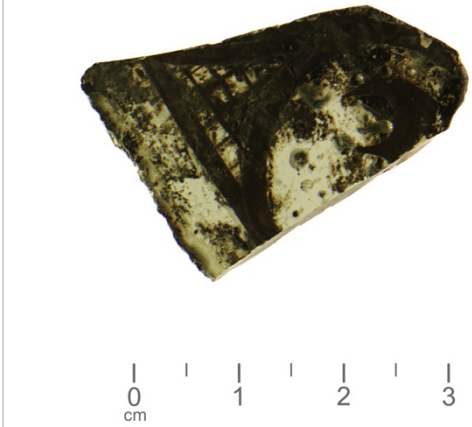

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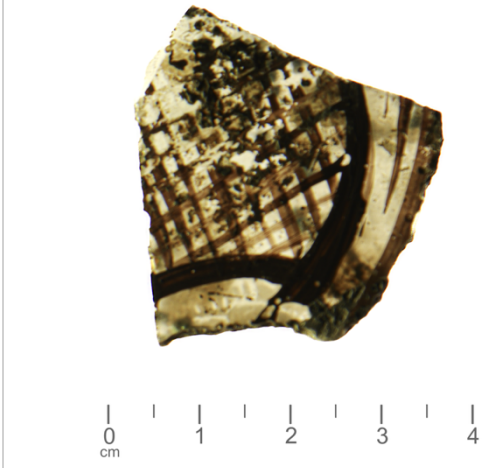

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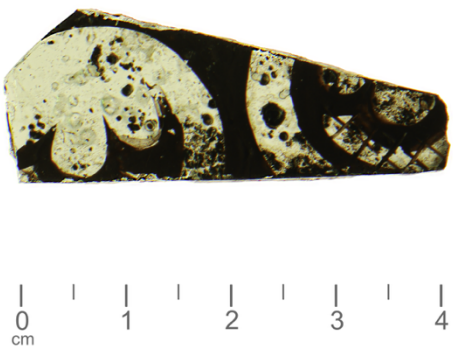

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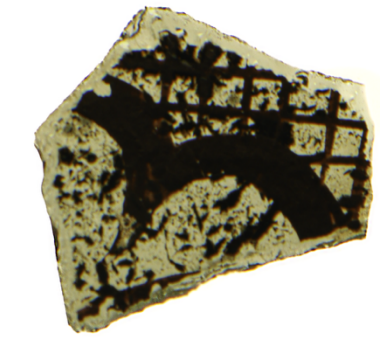

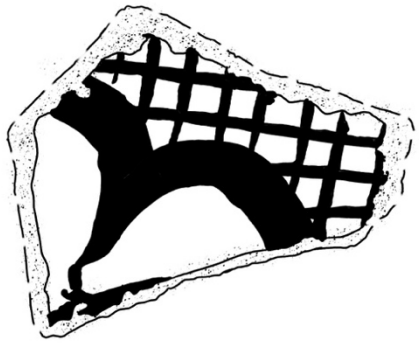

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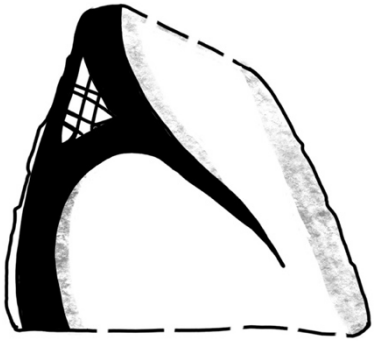

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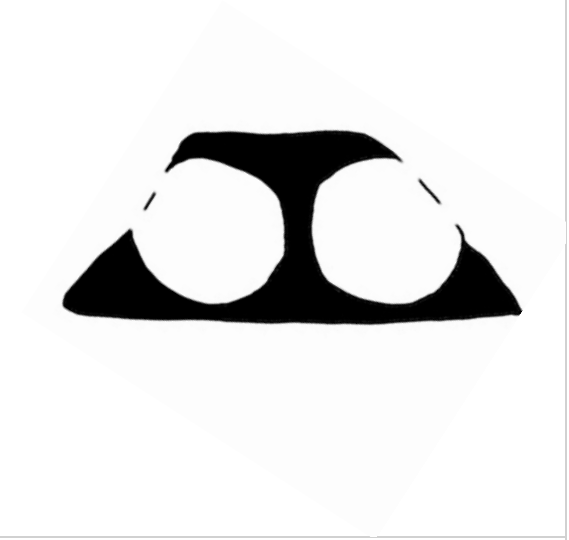

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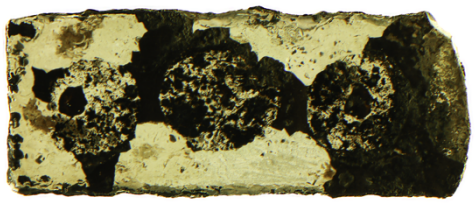

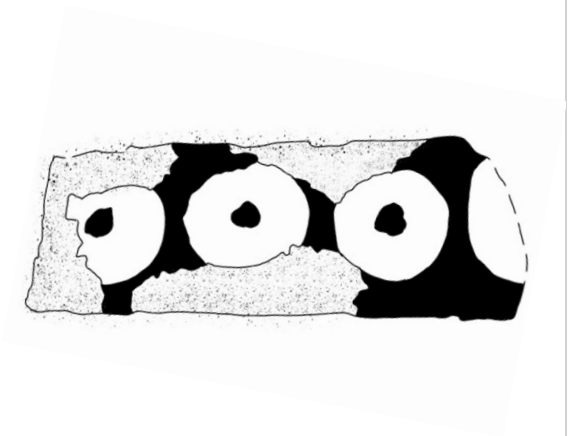

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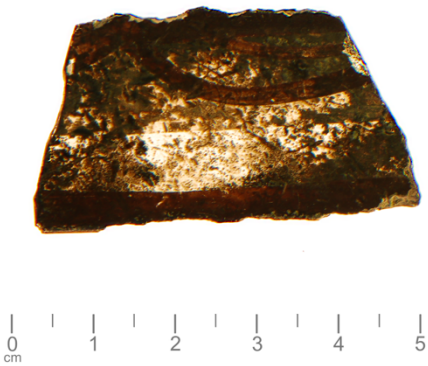

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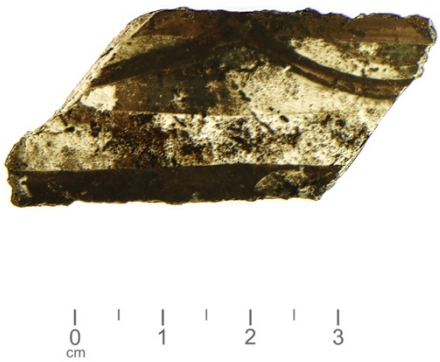

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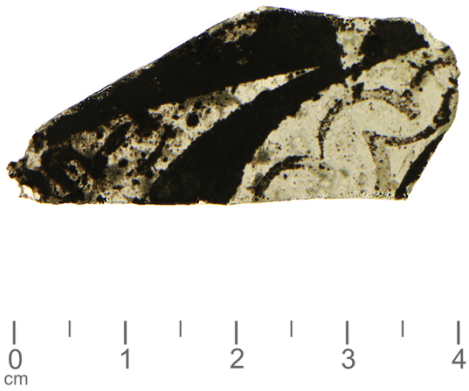

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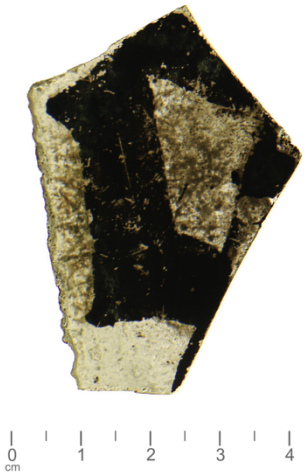

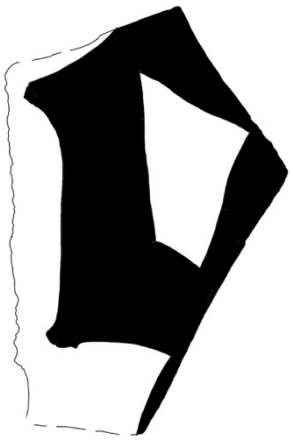

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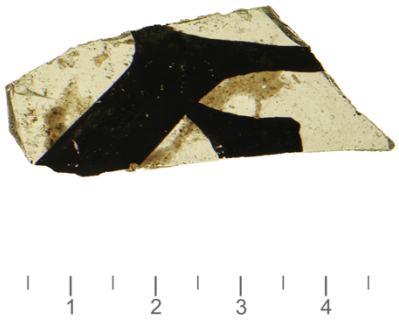

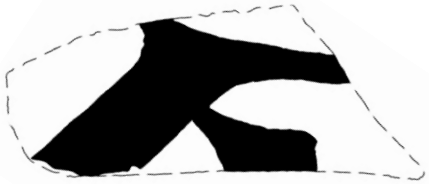

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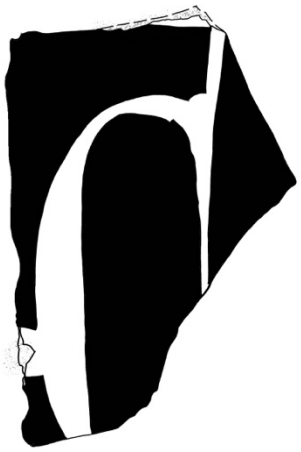

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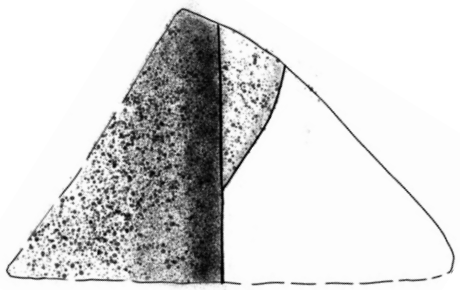

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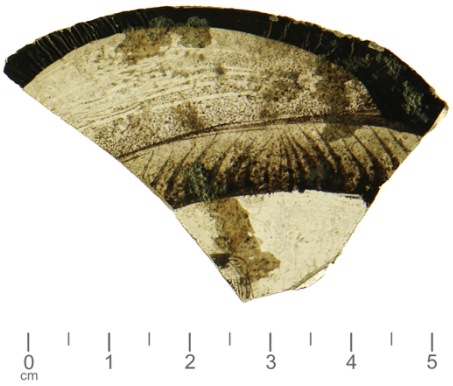

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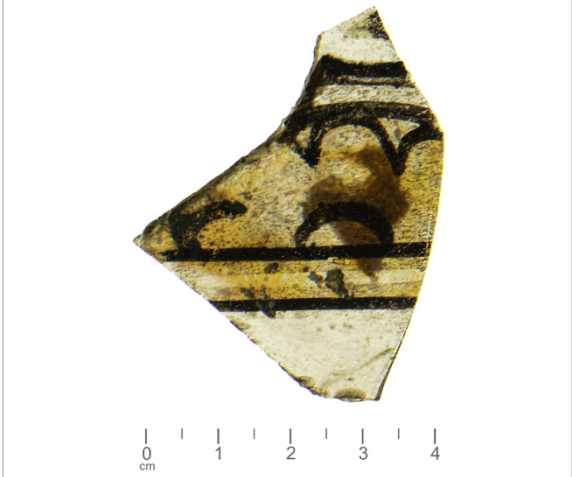

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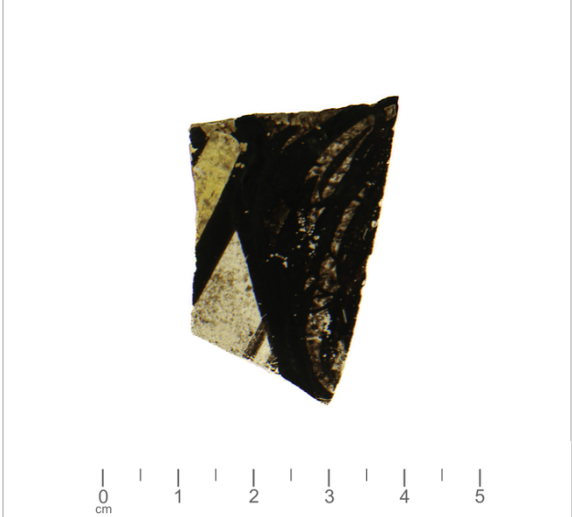

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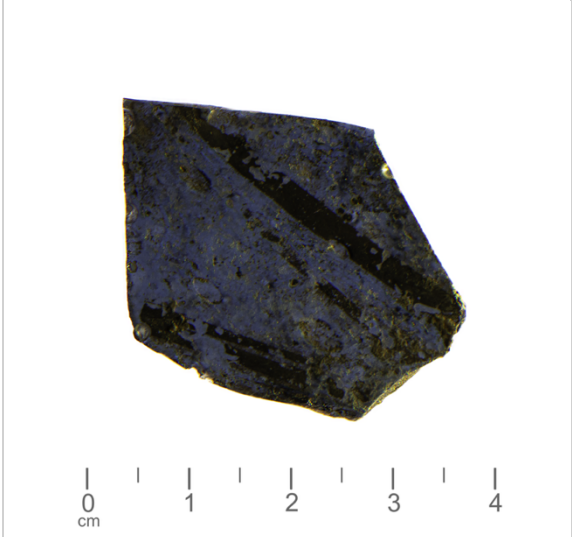

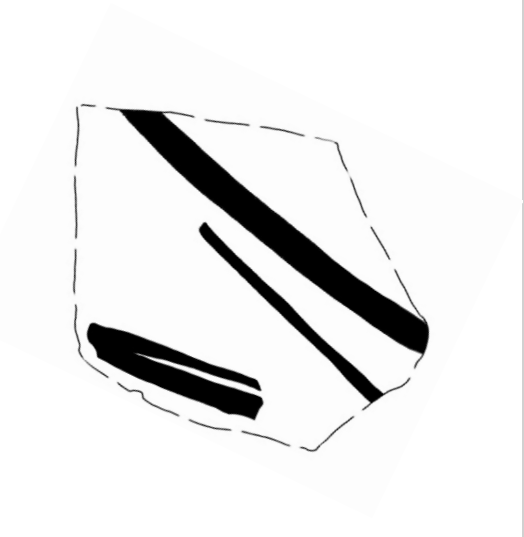

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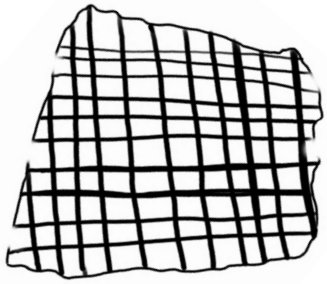

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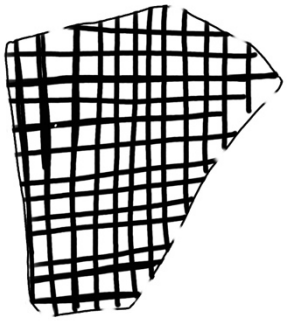

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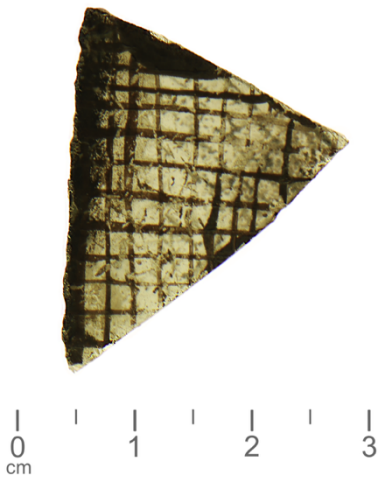

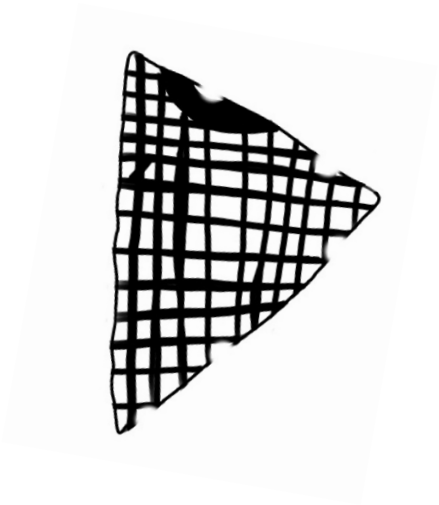

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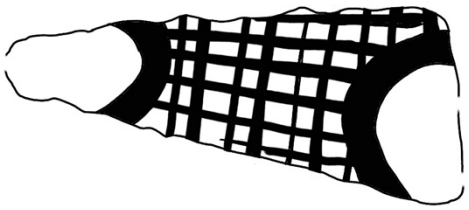

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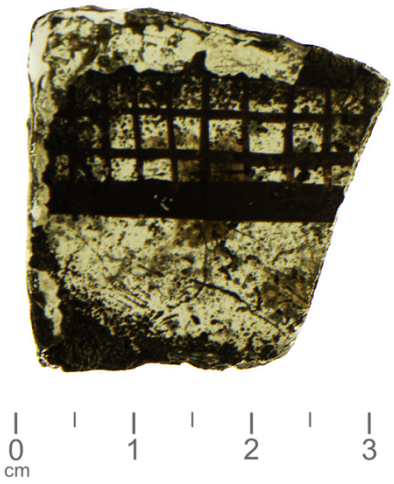

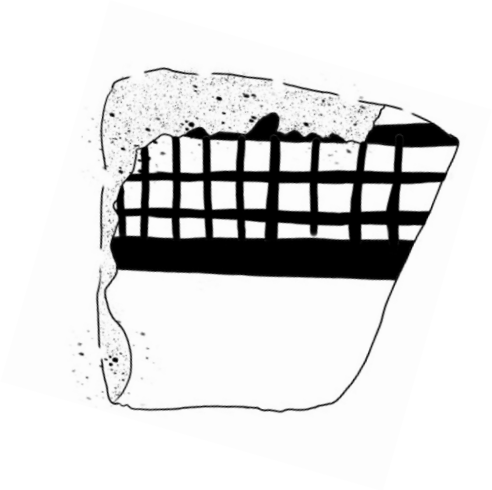

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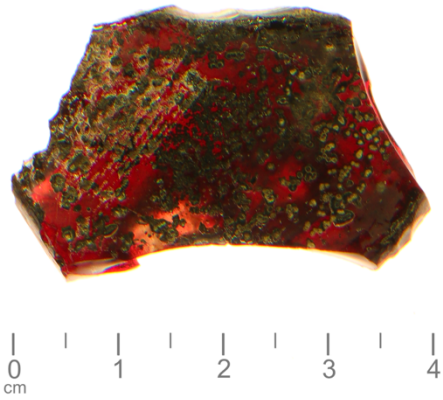

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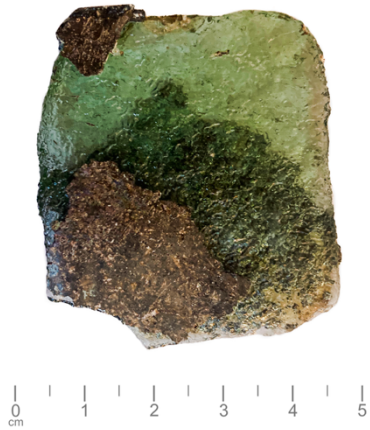

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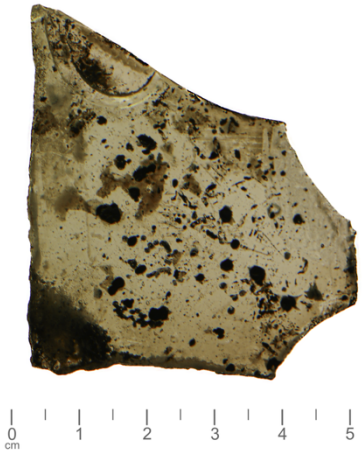

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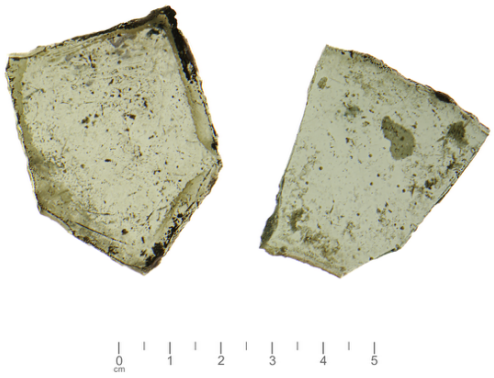

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L714

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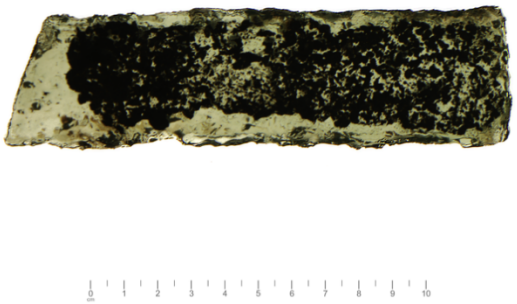
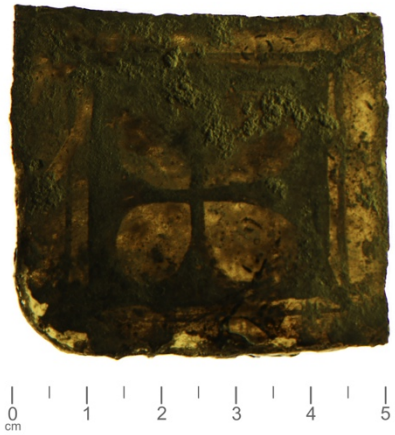
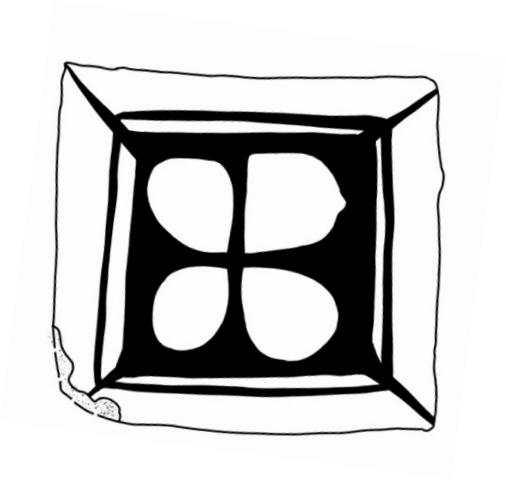


L806

L822

APPENDIX 68 RIEVAULX





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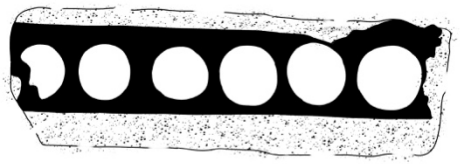
R2

R3

R4



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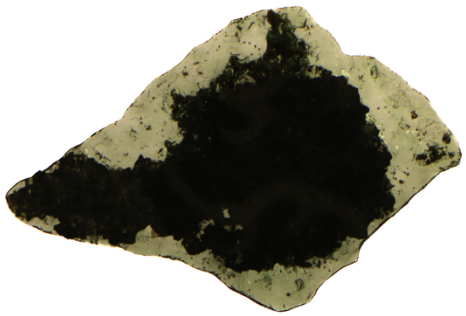

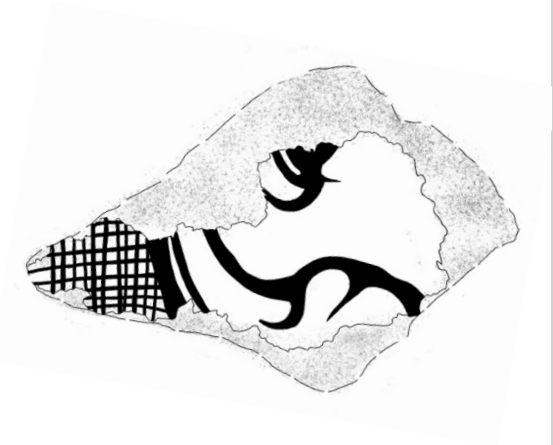

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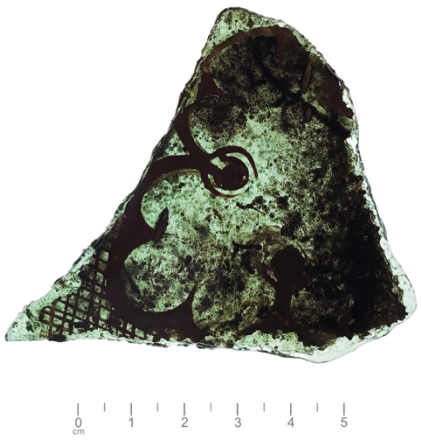

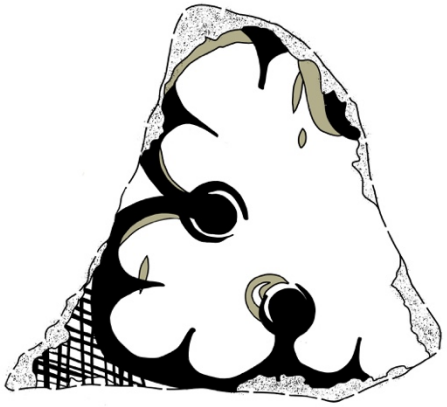

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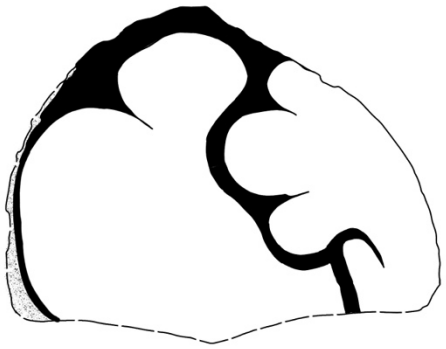

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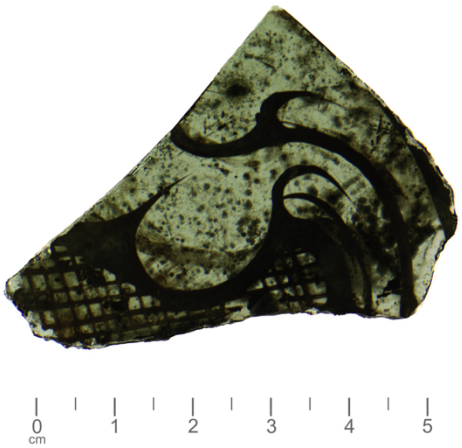

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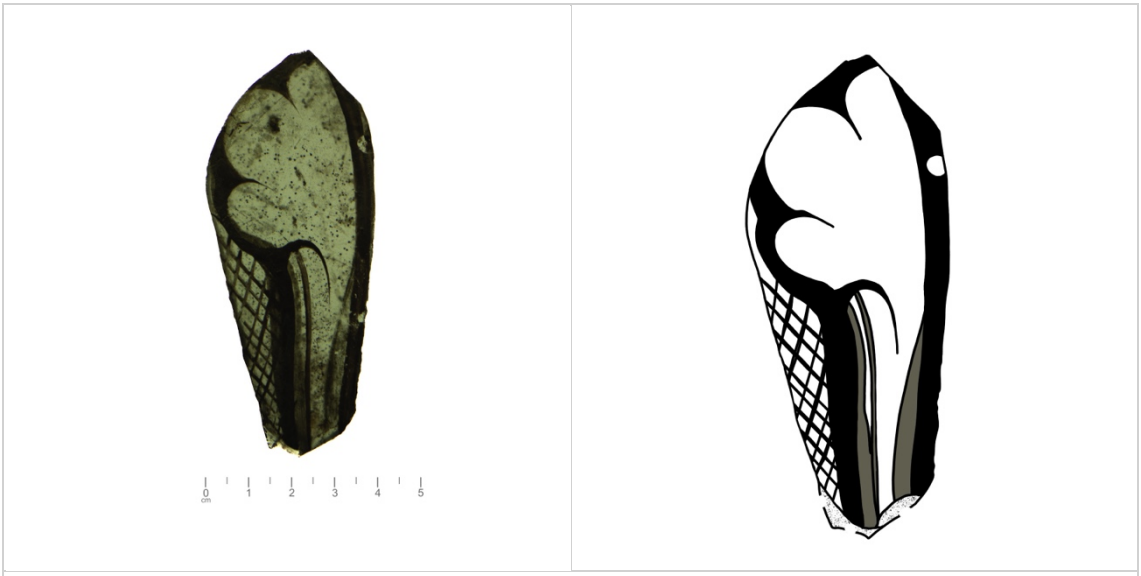

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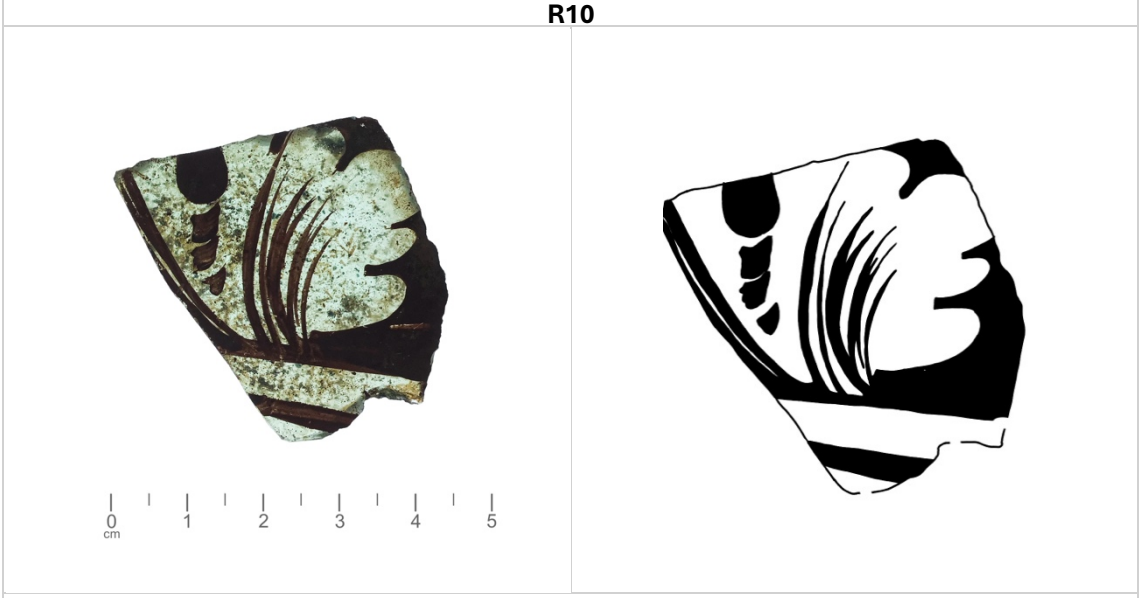

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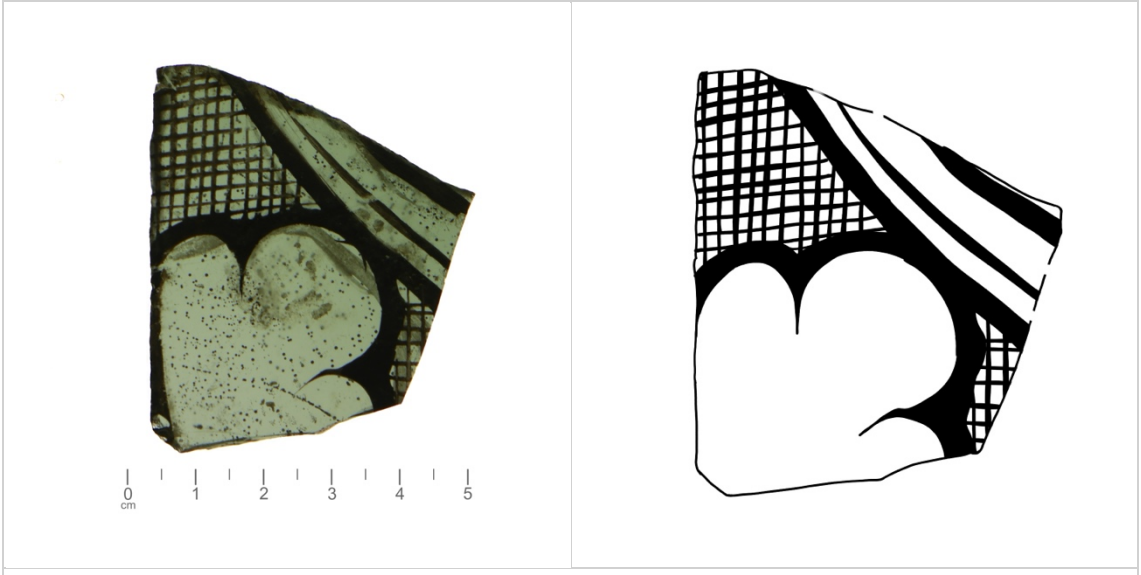

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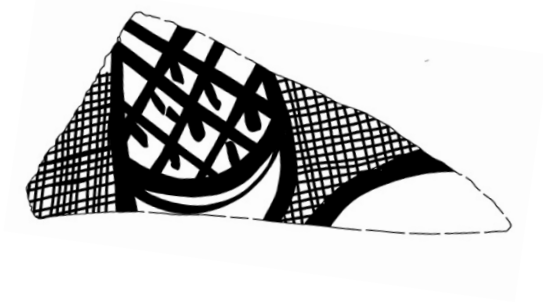

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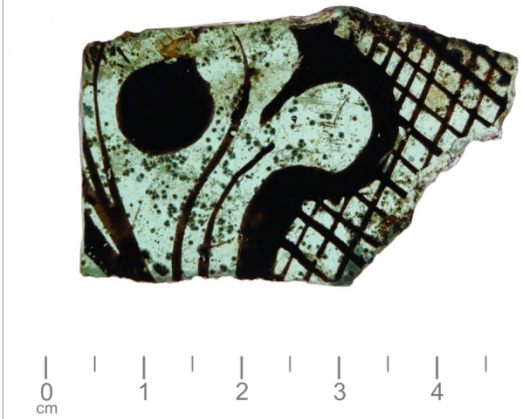

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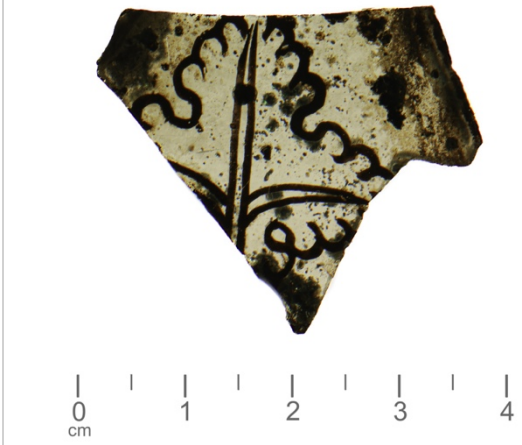

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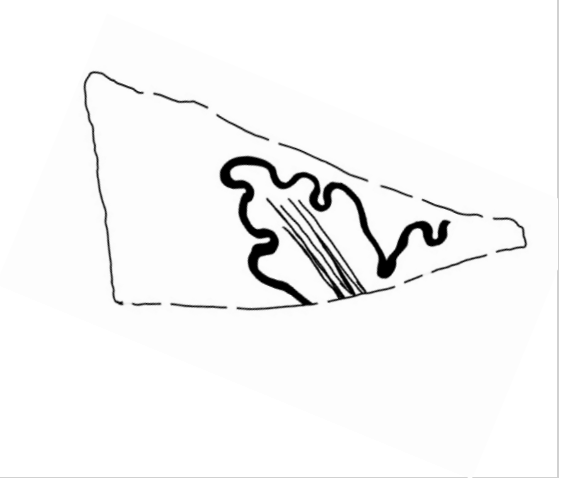

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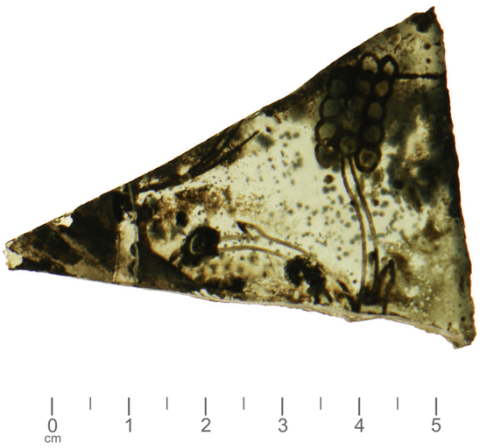

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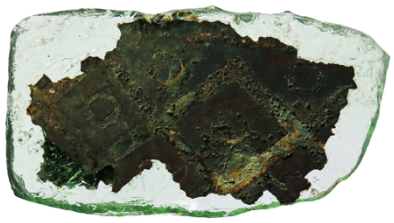

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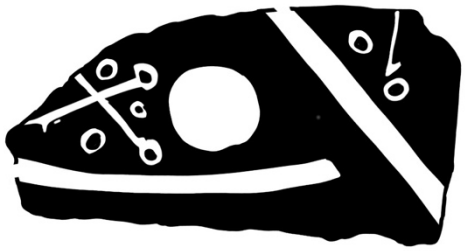

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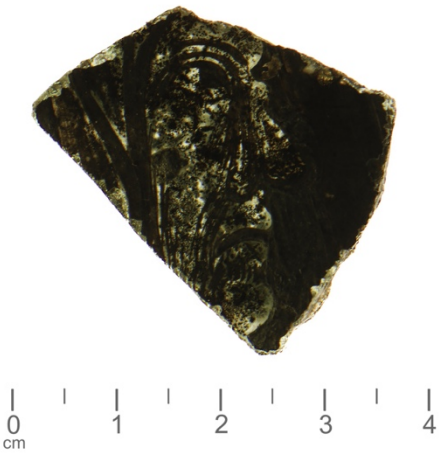

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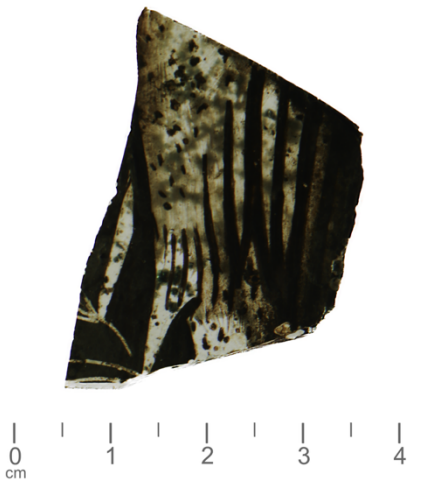

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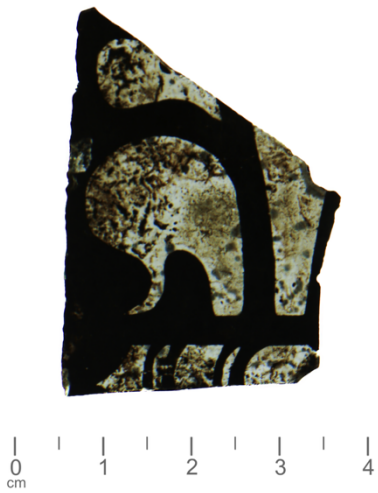

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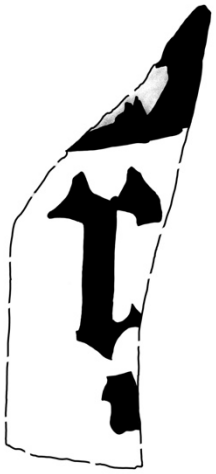

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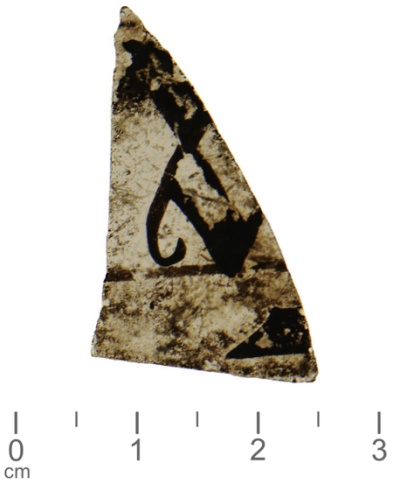

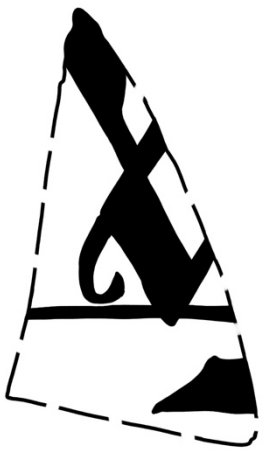

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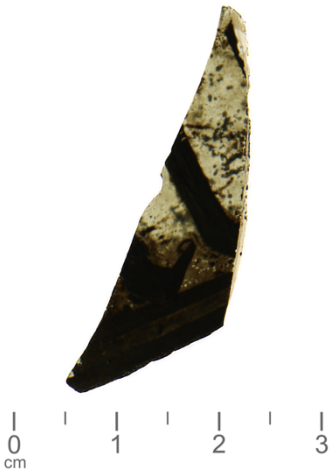

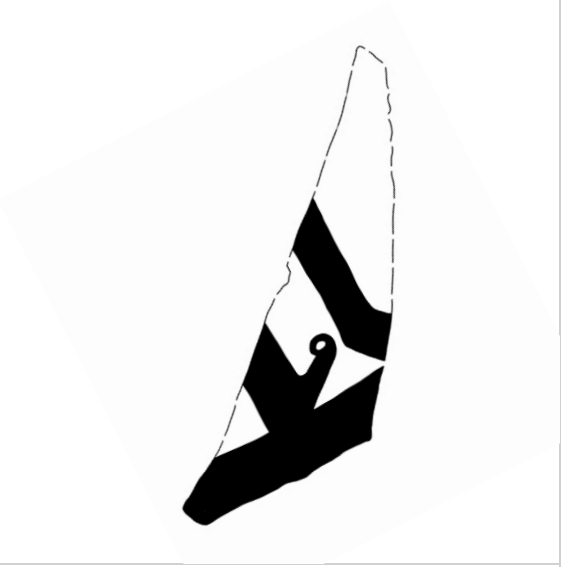

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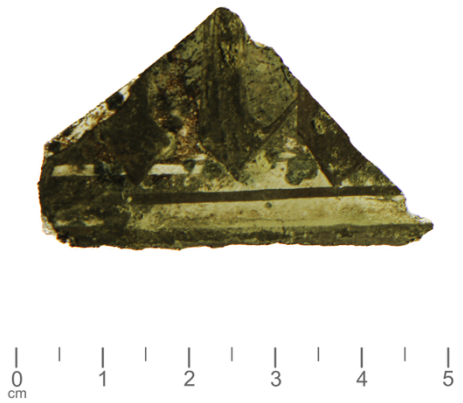

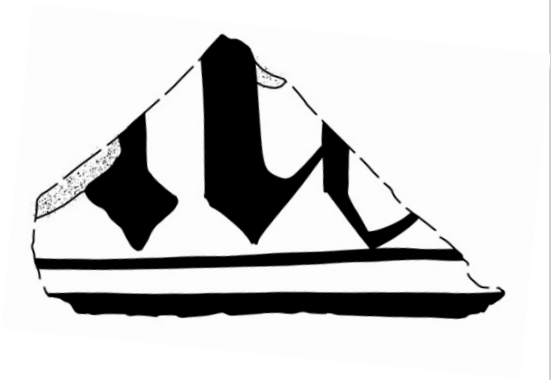

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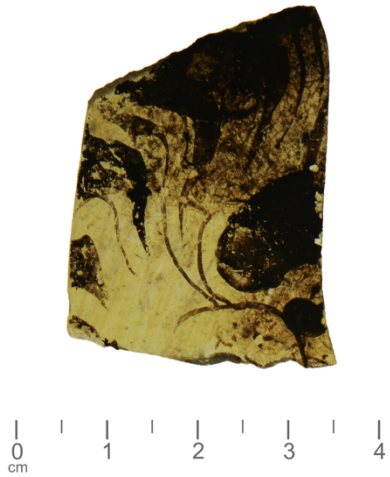

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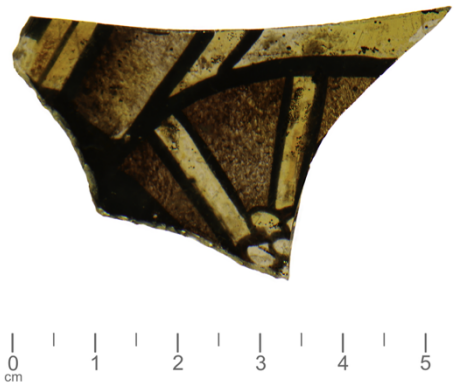

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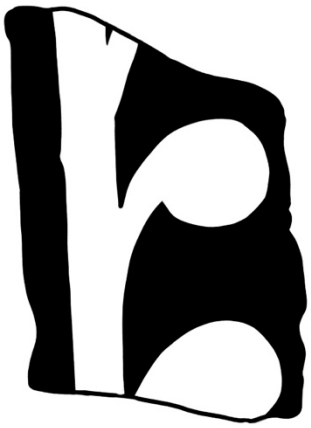

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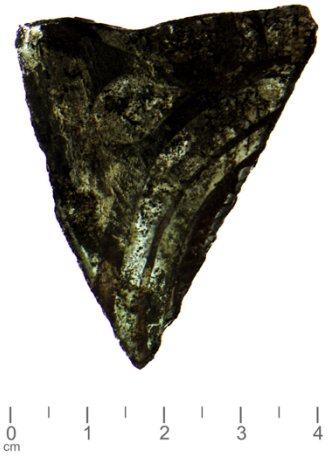

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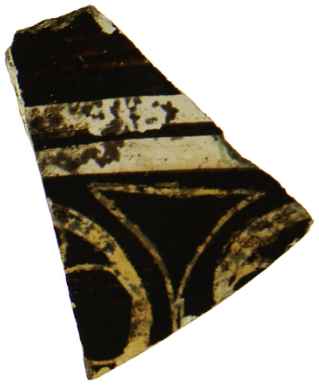

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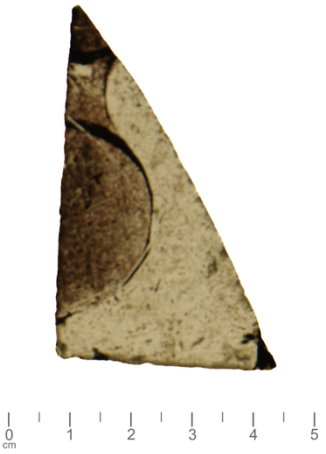

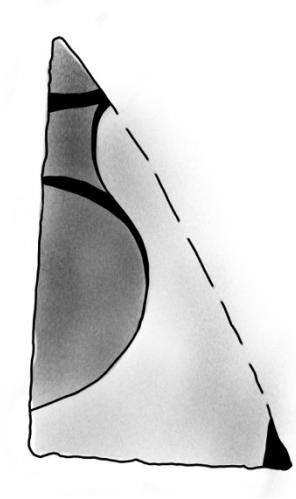

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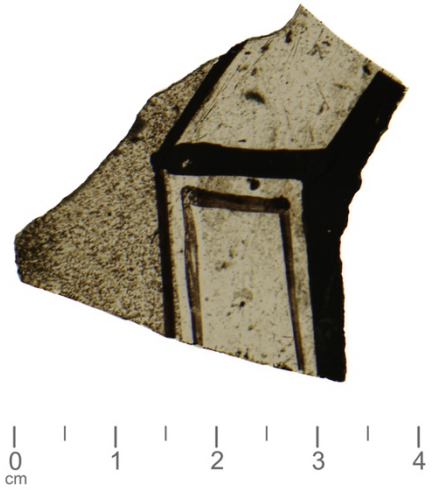

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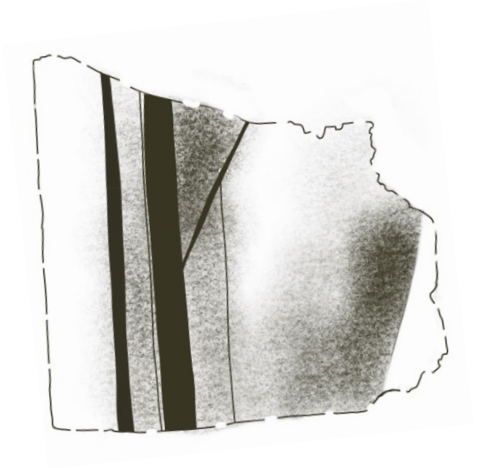

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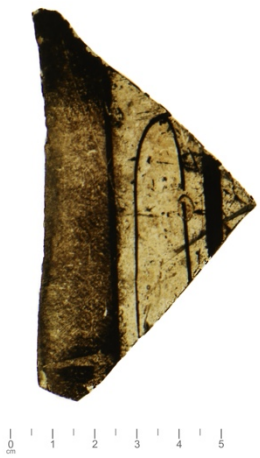

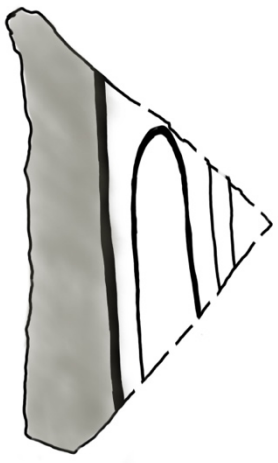

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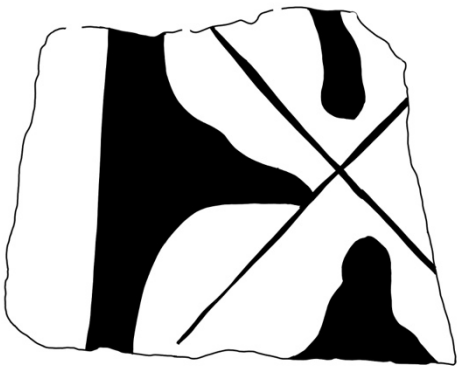

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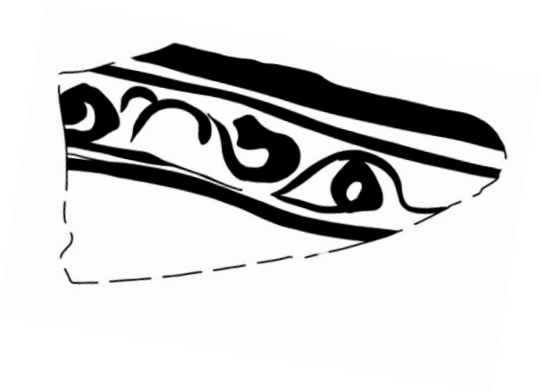

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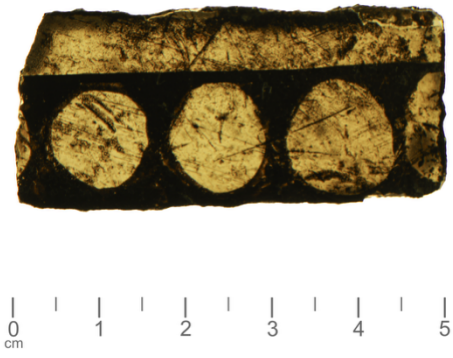

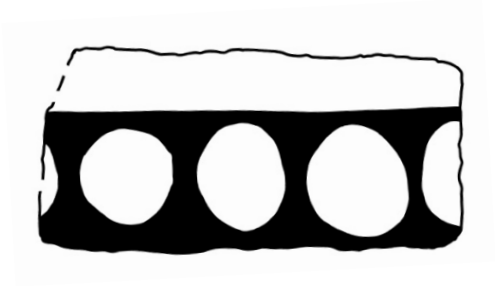

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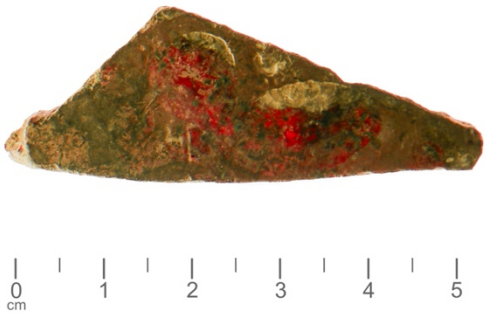

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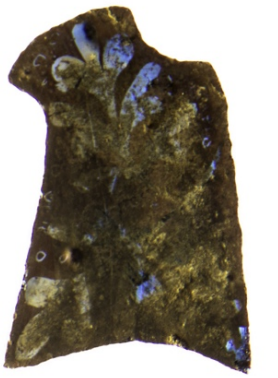

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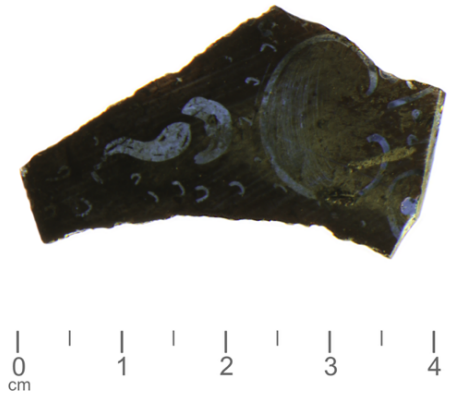

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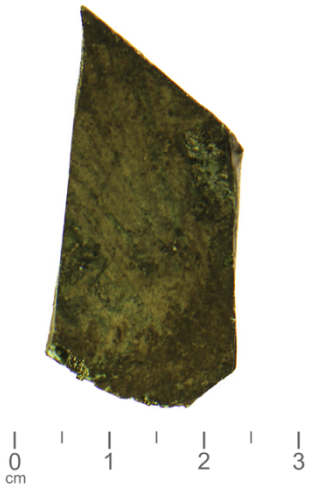

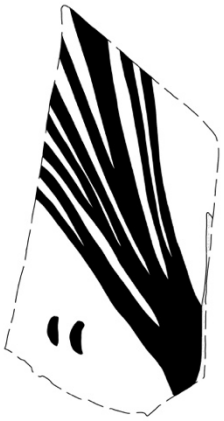

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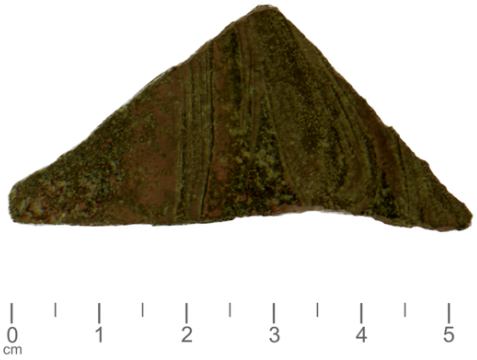

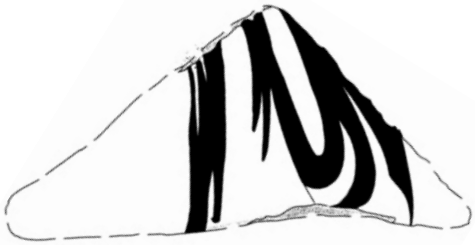

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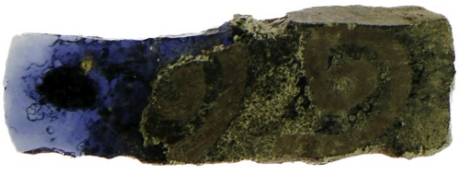

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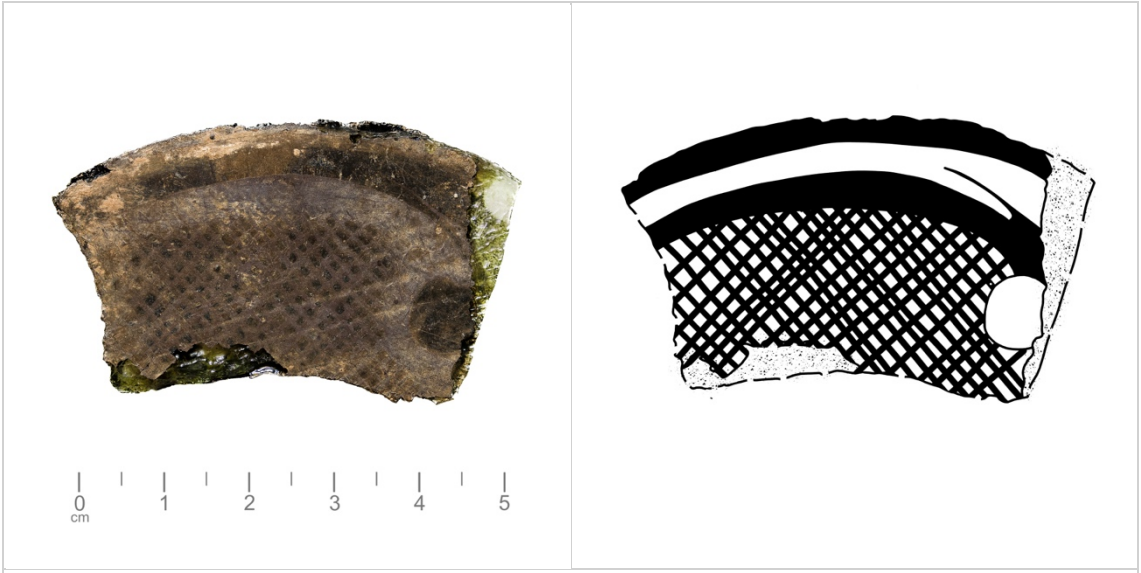
R54

R60

R61

R62

APPENDIX 69 WHITBY



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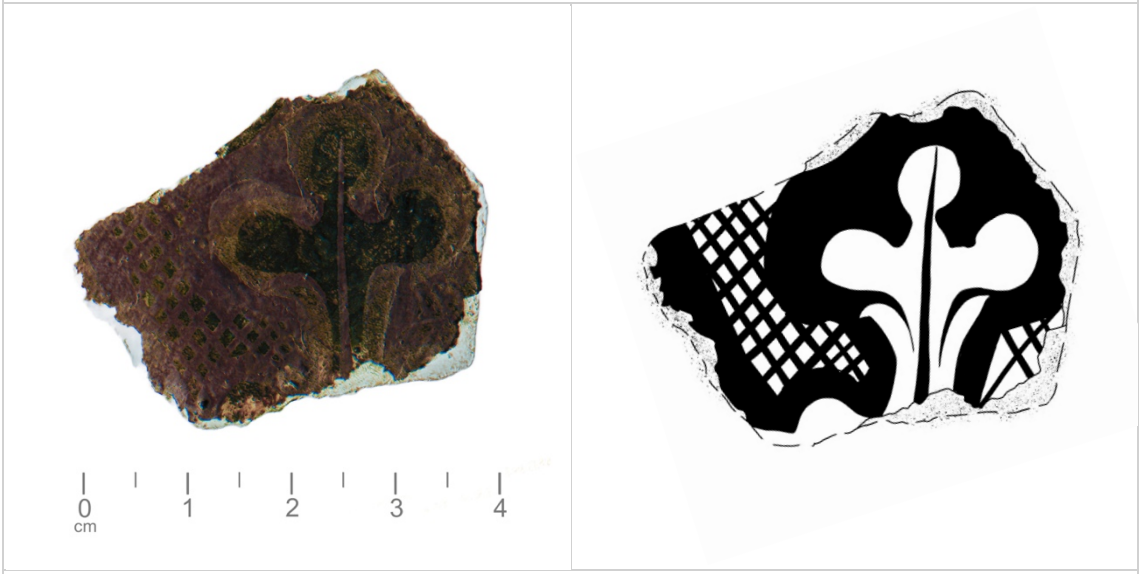

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W4

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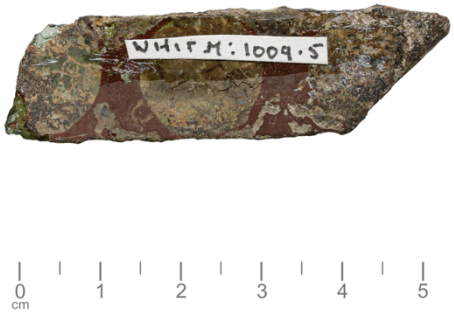

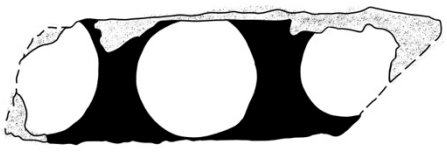

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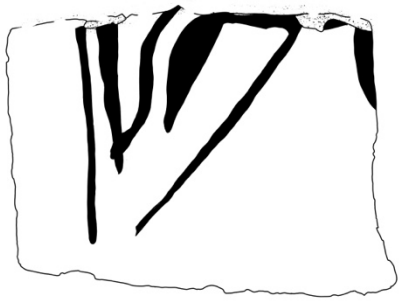

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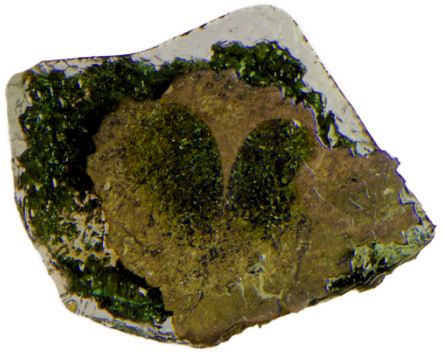

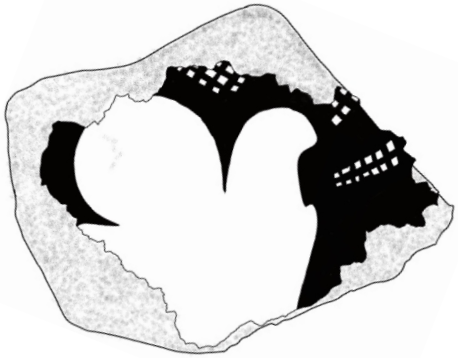

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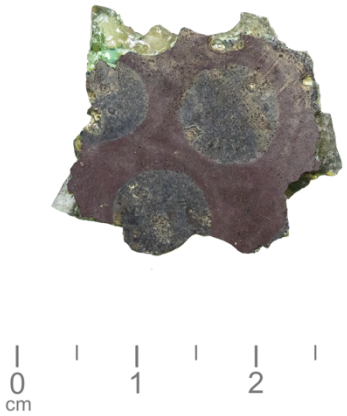

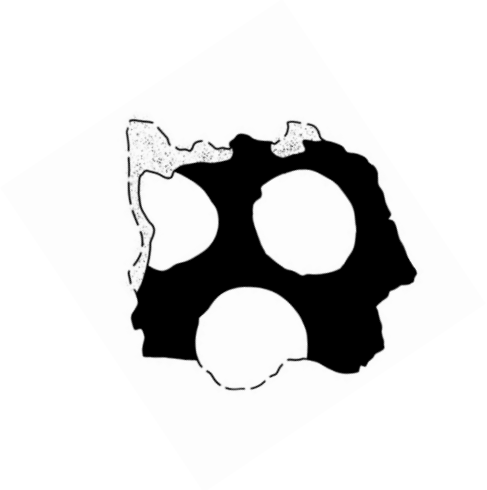

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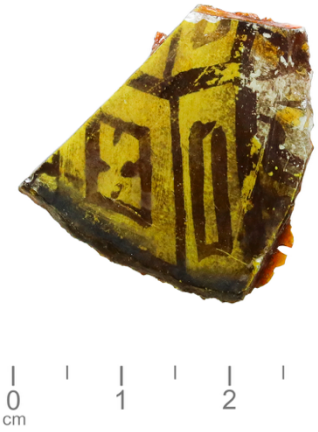

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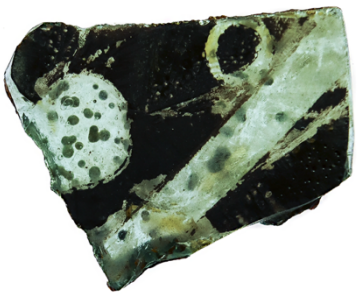

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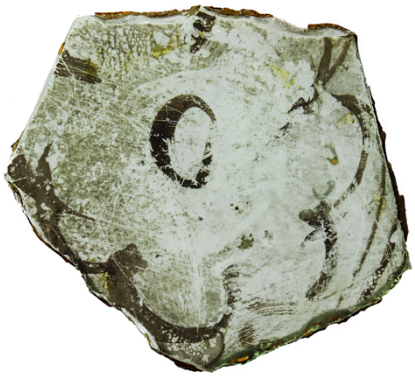

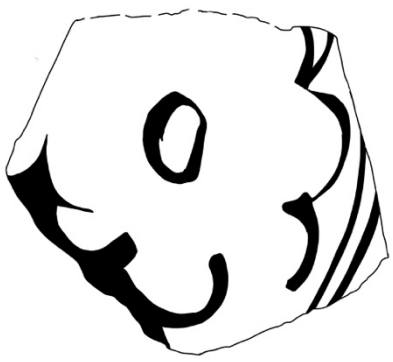

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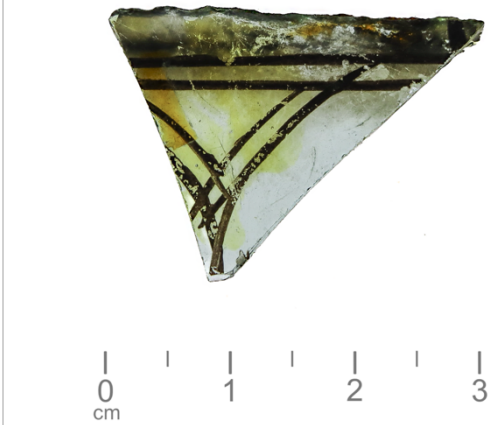

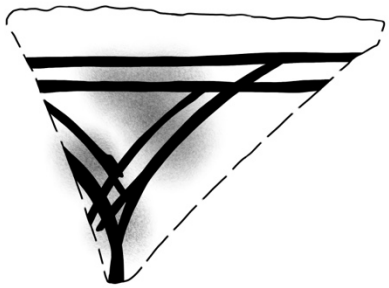

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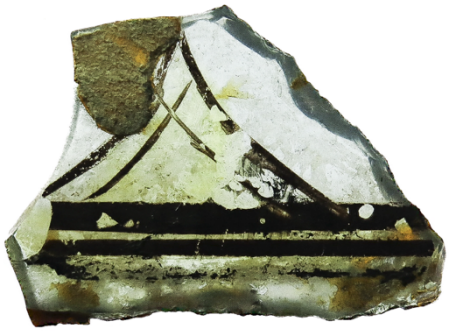

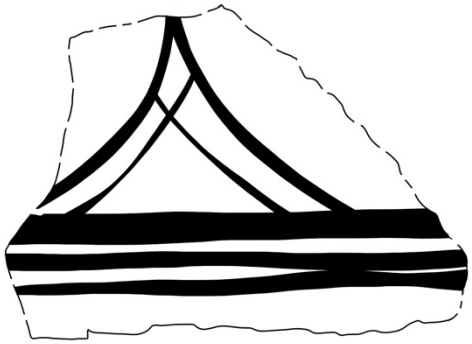

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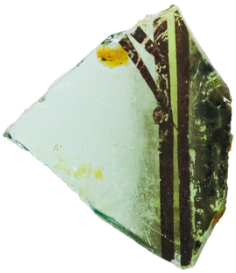

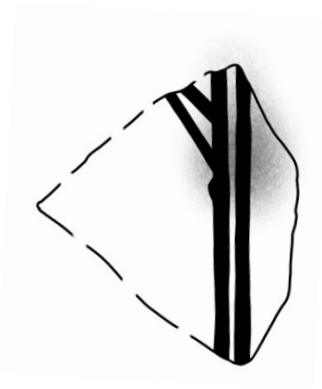

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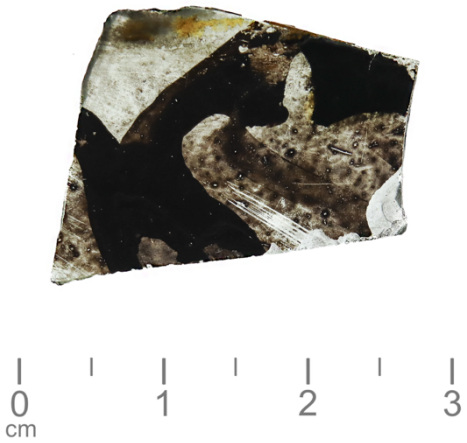

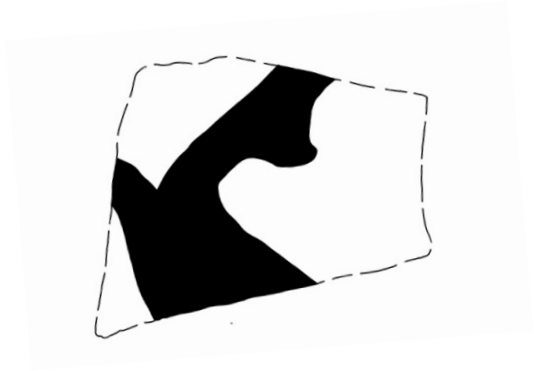

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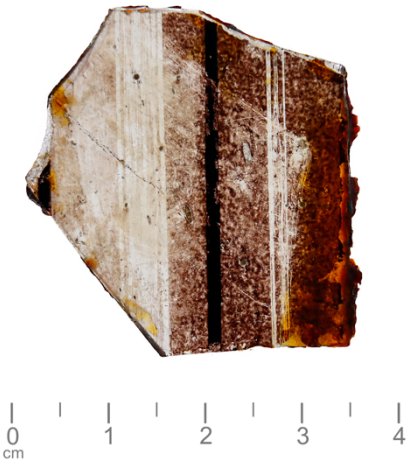

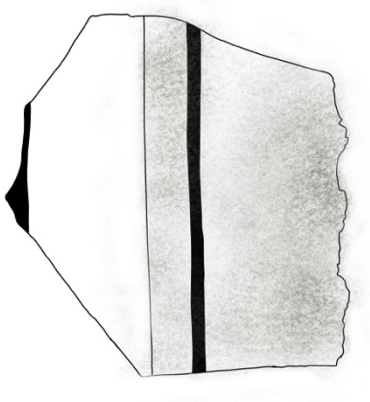

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W24

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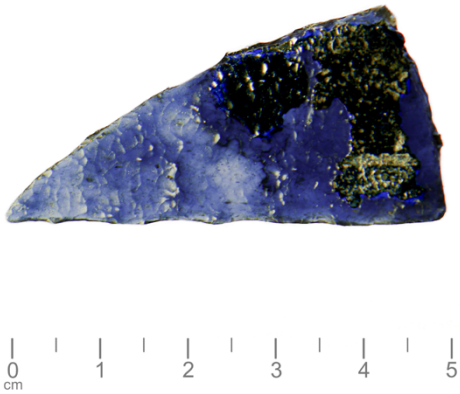

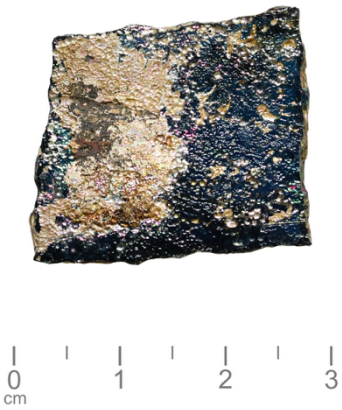

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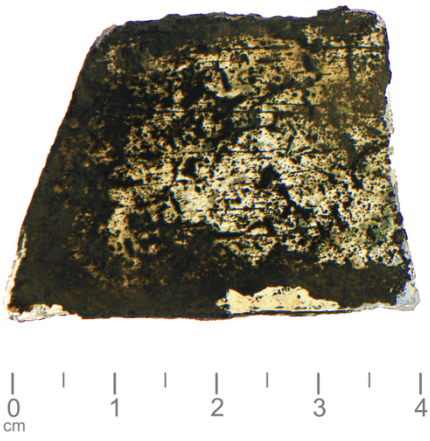

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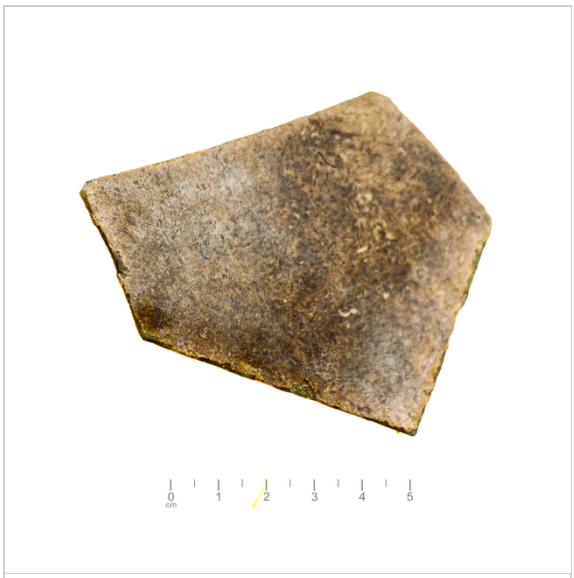

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