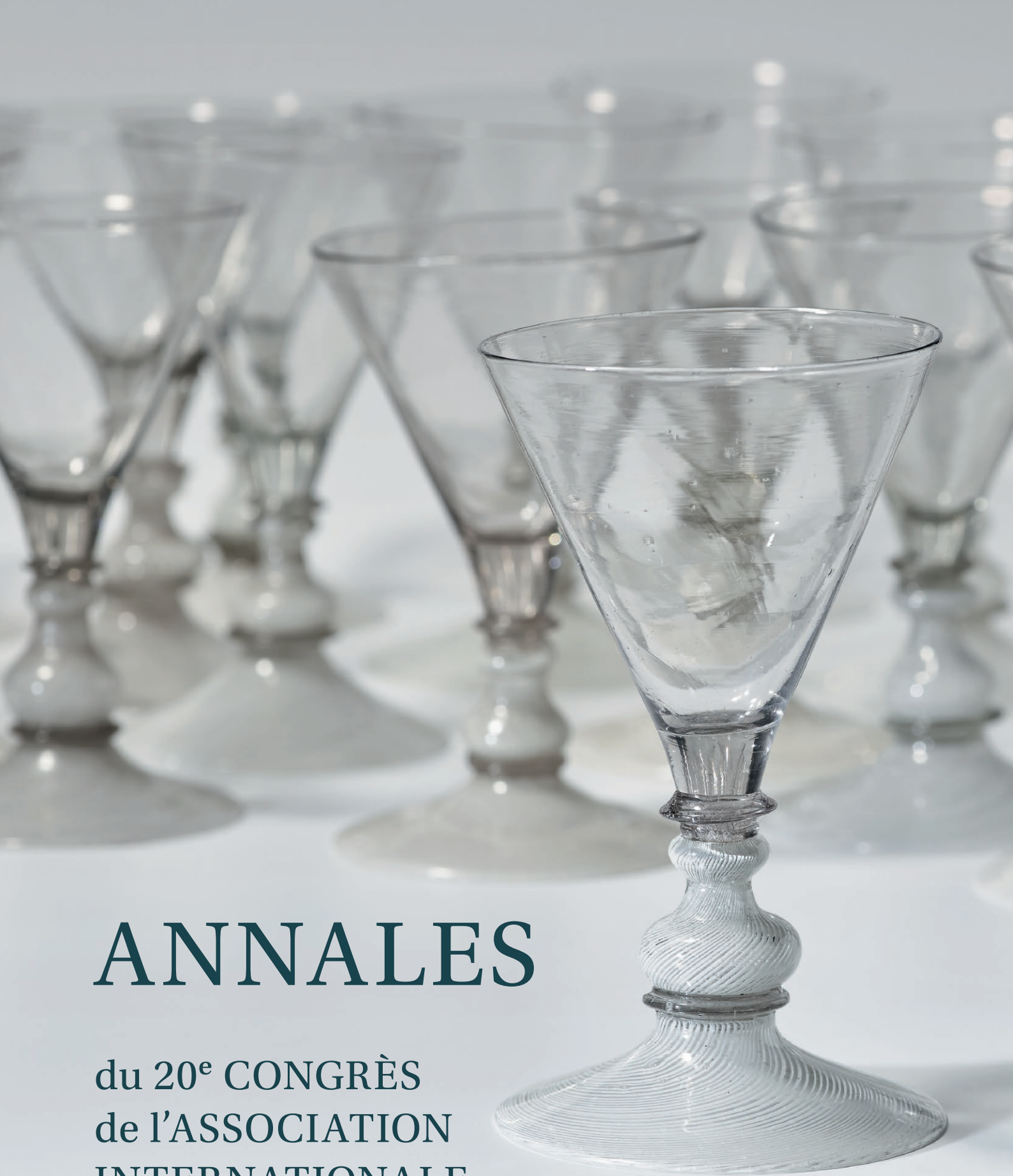

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Cover illustration
Goblets with white filigree decoration, produced in Swiss glasshouses, late 17th to early 18th century. From different Swiss public and private collections. For a detailed discussion see: Erwin Baumgartner, Reflets de Venise, Bern 2015, p. 254–272, 322–328 and the contribution of Christophe Gerber in the present volume, page 564.

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MEDIEVAL WINDOW GLASS IN SCOTLAND

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When compared to other parts of Europe, Scotland has a lack of both documentary and artefactual evidence for the use, working and manufacture of glass. There is no undisputed evidence for glass manufacture from its raw materials in Scotland until 1610, when the first patents for glass manufacture were issued.[1] The earliest excavated glass furnace, in which glass was directly made from its raw materials, is situated at Morison's Haven, East Lothian[2] and is dated to the late 17th–early 18th century. Centres of industrialised glass manufacture are known to have existed in England and Ireland in the later medieval and post-medieval periods.

It may be considered unusual that there was no attempt to produce glass in Scotland in the medieval period, when abundant raw materials were available in the region to make glass in the Northern European medieval glass-making tradition. However on the Northern fringes of Europe other countries show no evidence of a manufacturing glass industry until the post-medieval period – for example Finland, where there is no evidence of glass production until 1681.[3]

Scottish window glass from the medieval and post-medieval periods is being studied by a Research team at Heriot Watt University, Edinburgh. The research focuses on the scientific analysis of the composition of window glass – both archaeologically excavated fragments and in-situ panes from post-medieval and industrial buildings. The research into the scientific analysis of medieval window glass will aim to answer questions such as where was the glass manufactured, such as which trade routes brought glass into Scotland and where the craftsmen who worked on glazing Scottish buildings came from. Whilst research has taken place accounting for these factors from 1610 onwards,[4] very little research has taken place focusing on the pre-1610 era.

WINDOW GLASS IN SCOTLAND PRIOR TO 1000 AD

Glass beads from the Iron Age are the earliest evidence of the use of glass in Scotland. The discovery of the Iron Age industrial site of Culduthel in Inverness-shire has provided evidence of low-temperature glass working, primarily the making of beads in a local style but using an imported, heavily recycled natron glass.[5]

The earliest evidence for windows and glazing come from Roman buildings – particularly military lodgings along the line of the Antonine Wall such as at Crawford Roman fort in Lanarkshire, Falkirk[6] and civilian buildings such those at Inveresk in East Lothian[7]. So far no evidence has been found to show these window panes were made in Scotland, nor have any Roman glass-working sites been discovered in Scotland.

There is a gap in evidence for glazing until the earliest medieval Scottish window glass fragments, which have been found in excavations at the Whithorn monastic settlement in Dumfries and Galloway.[8] 132 sherds are associated with an 8th–9th century chapel building which was thought to be a timber building. The completed windows may have been made elsewhere and then transported to Whithorn in their wooden frames, or the flat glass may have been brought to site and then made into windows. Scientific analysis found the glass to be predominantly of natron glass although it may have been partially adulterated with plant ash glass as some fragments have a composition lying midway between a typical natron and sodic plant ash. The glass was very similar in chemical composition to that found at Jarrow and Monkwearmouth in North-East England. As well as window glass, numerous glass vessels have also been found at Whithorn and one author has suggested that some of these vessels may have been made in Scotland. Campbell[9] identifies a vessel Group 'E' that he suggests may represent production in Scotland by continental glass makers. They have a typology unique to the site and may represent a local attempt to imitate imported goods for a short period during the 6th century. If this is the case, could the same glass makers also have made the window glass on site?

Other Scottish early medieval sites, including Iona and Dunadd, have also yielded glass finds and potential evidence of glass working, including bi-chrome glass rods, possible cullet and moulds, but no evidence of window glass.[10]

A crucible containing glass working residue was found in a small industrial complex at the 8th century Pictish monastic site at Portmahomack, Tarbet Ness.[11] This opaque yellow glass waste was found to be a soda-rich glass, coloured

1 Turnbull 2001, 1.
2 Cressey et al. 2012, 36.
3 Kuisma-Kursula and Raisanen 1999, 72.
4 Kennedy et al. 2013, 465.
5 Bertini et al. 2014, 256.
6 Keppie and Murray 1981, 248.
7 Thomas 1988, 158.
8 Cramp 1997, 327.
9 Campbell 2007, 73.
10 Lane and Campbell 2000, 174.
11 Peake and Freestone 2011, 18.

and opacified with the addition of lead antimonite. The small crucible and the limited amount of glass residue found within an area of more general metalworking suggest the glass made would have been used as decorative enamel work. The buildings on the site at this period were thought to still be made of timber and there is no evidence that vessels or window glass were produced.

There has so far been no evidence for larger-scale glass working in Scotland during this period – such as that found at Glastonbury Abbey in England, where four furnaces and a large amount of glass working waste were excavated in the 1950's but more recently associated with the founding of the Abbey in the late 7th century.[12]

MEDIEVAL WINDOW GLASS

Across Europe there are numerous examples of in situ stained glass windows in churches and cathedral buildings, however in Scotland virtually no in situ window glass survives from before the post-medieval period. Almost all the glass windows in ecclesiastical or monastic buildings were destroyed before, during or shortly after the Reformation in 1560. The trappings of the Catholic Faith were considered iconoclastic and in a short space of time churches and monastic buildings were stripped, despite the First Book of Discipline specifying that the windows of religious buildings should not be destroyed and remain glazed.[13] Some windows survived the initial destruction, such as the stained glass in King's College Chapel in Aberdeen, which survived into the 17th century. However, the lead cames and glass cullet would have been valuable commodities and were soon stripped and removed from most buildings. At Elgin Cathedral there is evidence of lead-smelting activity in the years following the Reformation, which probably included recycling the lead cames.

The earliest 'in situ' pieces of late medieval window glass known to survive are two small heraldic panes depicting the coat of arms of Mary of Guise, thought to have been made between 1541 and 1547 and installed in Magdalen Chapel, Edinburgh (figure 1). A few fragments of pre-reformation window glass were incorporated into two modern pointed windows, now in the coffee shop in the crypt of St Giles Cathedral, Edinburgh. There is also reference to an early 20th century panel made from fragments of medieval stained glass originally found at Holyrood Abbey which was created to be put on display in Holyrood Palace.[14] This has recently been located in the stores of the Royal Collection.

For a number of reasons glass from the medieval period is found in lower quantities in excavations in Scotland compared to the rest of the United Kingdom. It is probable that glass was less common in Scotland, certainly in a domestic context. Even high-status buildings such as the Scottish Tower Houses have little evidence of being glazed until the late 15th century and in most cases much later. Glass found from this period is heavily corroded; the surfaces have been leached of lighter alkali ions and have been replaced with insoluble black crusts. The highly acidic burial conditions

Fig. 1: 'Arms of Mary of Guise, Magdalen Chapel, Edinburgh' © Kim Traynor – Own work. Licensed under CC BY-SA 3.0 via Commons – https://commons.wikimedia.org/wiki/File:Arms_of_Mary_of_Guise,_Magdalen_Chapel,_Edinburgh.JPG#/media/File:Arms_of_Mary_of_Guise,_Magdalen_Chapel,_Edinburgh.JPG.

in many regions of the country accelerate decay, combined with the original chemical composition of this type of glass, resulting in poor preservation.

The last major study and catalogue of medieval stained window glass in Scotland was carried out by Dr Pam Graves in 1985, who identified 18 sites where glass had been found. Since then further excavations, such as at Inchaffray Abbey,[15] Pluscarden Priory,[16] Elcho Nunnery[17] and Perth City Centre[18] have uncovered significant assemblages. In addition, reassessments of the window glass assemblages found at Elgin[19] and nearby Spynie Palace[20] have been carried out. A project to catalogue the window glass assemblage from St Andrew's Cathedral is ongoing at Historic Environment Scotland.

The majority of the medieval glass found in Scotland has been dated to the 13th century. The majority of the glass is 'white' – colourless glass with a smaller percentage of coloured pot metal glass. A minority of the glass is painted with 'grisaille' decoration comprising mainly foliate patterns, geometric borders and cross hatching (figure 2). Graves[21] noted that Coldingham Abbey was the only Scottish site that had yielded a recognisable glass fragment with a painted figure. This is unusual when considered alongside the large figurative stained glass windows still present in

12 Willmott and Welham 2013, 82.
13 Spicer 2003, 32.
14 Eeles 1915, 81.
15 Ewart 1996, 469–516.
16 McCormick 1994, 391–432.
17 Reid 1988, 68.
18 Bowler et al. 1995, 917–99.
19 Murdoch 2013, 1–16.
20 Graves 2002, 132–137.
21 Graves 1985, 153.

Fig. 2: Glass fragments found at Elgin Cathedral showing the grisaille decoration. © Robin Murdoch.

most of the great English and European cathedrals. Dating of glass by typological styles is based on English and French dated windows that remain in situ, and it is possible that the development of window decoration in Scotland may not have followed the same trajectory. Graves believed that many of the Scottish fragments exhibited both French and English characteristics with some motifs such as a double trefoil and fine cross hatching are possibly unique to Scotland. At Melrose, there are three distinct styles, one reminiscent of French flamboyant tracery, one of English perpendicular tracery and a style that Graves[22] suggests is native Scottish work. The mechanics and procedures of making windows would lead to the assumption that glass painters were at work in Scotland. Even though there is no physical evidence of this, the identification of unique stylistic qualities would support this conclusion.

Many new religious houses were established in the 12th and 13th Centuries. The East Coast ports of Aberdeen, Perth, Dundee and Leith all traded extensively with Europe – particularly Bruges and Flanders, Artois and Picardy, and these routes would have been the most likely for glass importation. There is therefore ample evidence for trade with other European countries where glass production was well established at this point. However, no documentary record of glass importation has been found so far.

The number of large cathedrals and monasteries being built simultaneously across Scotland would suggest that master glaziers and their apprentices, who cut and painted the glass, must have been working extensively in Scotland, but unfortunately little evidence of this remains.

The earliest documentary reference to window glass being produced in Scotland is that glass for the 13th century Dornoch Cathedral was made at Sideray – about two miles from Dornoch.[23] This is taken to mean that imported flat glass was cut, painted and fitted into framework for the windows, rather than the glass itself being made on site. The See of Moray records that 'Richard' the glazier was employed at Elgin cathedral in 1237, while at nearby Spynie Palace there is reference to a window being installed in an extension in the mid-13th century, by the glaziers employed to glaze Elgin Cathedral at the time in St Andrews, writing on the tomb of a person named 'Gray' records he was a 'vitrarius' of the metropolitan church in St Andrews and in Ayr, a Friar called John Strand, who died in 1517, was described as a 'vitrifaber' and recorded as working for the Greyfriars around Scotland – including at Perth, Ayr, and Elgin.[24]

LATE MEDIEVAL PERIOD

The economic boom in the 12th and 13th centuries gave way to a much more unstable economy in the 14th century. The conflict with England led to the seaways being blockaded and the potential for trade diminished. Glass was maybe not as important a commodity in times of war and unrest. Very little ecclesiastical window glass from the later period is found in the archaeological record although window glass found at St Andrews and Dunfermline is likely to be dated to the early 14th century.[25]

An account written by the Customers of Linlithgow in the Exchequer Rolls for Scotland records that glass for windows was given to the Abbey of Paisley, by Robert II around 1371–1390. There is also a record that it was a Hanseatic merchant who brought 'the best master of stained glass windows in the world' from Lubeck [Northern German port] perhaps to glaze James I Charterhouse at Perth but the Florentines were extremely anxious to have him return to his native Italy to work on their Cathedral in 1438.[26]

It is possible that every large-scale ecclesiastical or monastic stone building would have been glazed at some point during its life. However, evidence suggests that Roslyn Chapel in Mid Lothian, despite being constructed 1446–86, was not fully glazed until 1736.[27] The building, notable for its complex iconographic and decorative stone carvings and design, has stonework around the windows that suggests glass was originally destined to be installed but whether due to the cost of the glass, difficulty in obtaining the glass or glaziers, or a change in design this was not completed until centuries later.

22 Ibid, 177.
23 Graves 2002, 132.
24 Graves 1985, 149.
25 Ibid, 181.
26 Caldwell 2015, pers. Comm.
27 Bambrough 2006, 18.

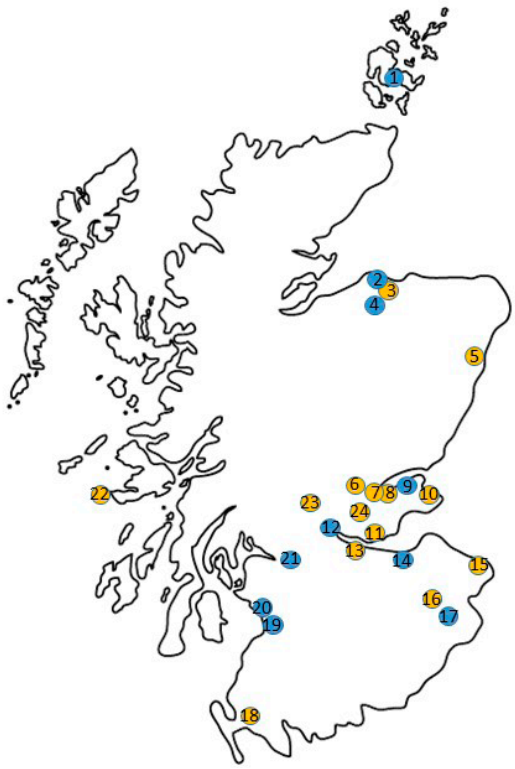

Fig. 3: Map showing locations of stained glass assemblages found in Scotland. The sites where fragments have been sampled for analysis as part of the project are highlighted in yellow. © authors.

DOMESTIC WINDOW GLASS

There is little evidence for domestic use of glazed windows in the medieval period. Excavations in the city of Perth for example have uncovered a small amount of window glass from middens and it is presumed that it came from ecclesiastical buildings, possibly the nearby Dominican Friary, but cannot be confidently associated with any building.[28] One piece of glass from Mill Street excavations, Perth, is the remains of a bullseye. This is from a context dated to no later than 1350, but probably late 13th century, and is evidence that glass is at least being cut from sheets in Perth at this date.[29]

Window glass fragments have been found at a number of late medieval castle sites. Fragments from Fast Castle from a context dated to the latter quarter of the 15th century were analysed and found to be of forest glass composition.[30] Glass of the 'forest composition' has also been found in recent excavations at the late medieval Palace site of Fetternear, suggestive of being made in the early 16th century,[31] and from Cromarty Castle[32] that is likely to have been made in the mid-late 16th century.

The earliest documentary records of domestic window glass being installed in Scotland come from 1550, recording glass windows being installed in a toll booth in Ayr on the West Coast, although part of the glazing is recorded as being glass panes being 'reused from other buildings'.[33]

Further work is ongoing, as part of this research project, to analyse late medieval and post-medieval window glass from Scottish domestic contexts[34] and compare the development of glass recipes in Scotland with the chronology established for English glass.[35]

SCIENTIFIC ANALYSIS OF SCOTTISH MEDIEVAL WINDOW GLASS

As outlined above the current evidence suggests window glass was imported to Scotland and then cut and decorated locally by craftsmen, before the final installation. However, this has not been corroborated scientifically.

Chemical analysis can quantitatively or semi-quantitatively identify the concentration of the main and trace elements in the glass. These results can be interpreted to provide information about the raw materials the glass was made from and the technologies used to make the glass. The aim of the current research is to chemically determine the composition of Scottish window glass from a wide range of sites. The results can then be compared with similar scientific studies of glass from England and Europe. It is hoped to identify similarities and differences in glass compositions and use this information to inform our knowledge of where and how window glass used in Scotland came to be made. For example, regional and chronological differences in glass composition in France and Germany have been identified chemically and researchers have therefore been able to differentiate between locally produced and imported glass.[36]

28 Hunter 2011, 120.
29 Bowler et al. 1995, 970.
30 Mitchell et al. 2001, 84.
31 Murdoch 2008, 55.
32 Murdoch 2015, 3.
33 Turnbull 2001, 53.
34 Kennedy et al. 2013, 465–78.
35 Dungworth 2012, 192–7.
36 Brill and Pongracz 2004, 125; Wedepohl and Simon 2010, 68.

Fig. 4: Elgin Cathedral. © authors.

Only a limited number of medieval glass window sherds have been subjected to scientific study in Scotland. Longworth and others[37] analysed five samples of glass from Elgin Cathedral using Mössbauer Spectroscopy. Tennent and others[38] reported on the analysis of twelve samples of glass from Elgin and St Andrews Cathedral by atomic absorption spectroscopy. Work was also undertaken at the National Museum of Scotland to analyse a total of eleven glass fragments from six sites by X-ray fluorescence in the 1980's, which are reported on in Graves.[39]

The analysis has shown that the glass, as expected, is of potassium-rich 'forest glass' composition. Rauret and others[40] included the analysis by Tennent and others in their data set used to perform statistical cluster analysis on elemental data comparing the twelve Scottish glass samples with 32 others from Spain, France, Germany and England. This showed that while assemblages from sites such as York, Ulm and Avignon form well separated groups, the Scottish compositions are distributed, suggesting that glass came from a wider range of sources. However, compared to England and the rest of Europe this is only a small sample and there is no published work on trace element or isotopic studies, and the need for study in this area is highlighted in the Scottish Archaeological Research Framework.

Assemblages of medieval window glass fragments have been identified and sampled from a range of sites across Scotland. Figure 3 shows all the sites identified where medieval window glass has been found. Sites highlighted are those where glass has so far been sampled for analysis.

The aim is to characterise the major and minor elements using a combination of scanning electron microscopy and energy dispersive X-ray fluorescence analysis (SEM-EDS) complemented by portable X-ray fluorescence (p-XRF) analysis which enables the analysis of heavier atomic elements.

ELGIN CATHEDRAL – PILOT STUDY

Initial analysis has so far been completed on an assemblage from Elgin Cathedral (figure 4).

Elgin Cathedral is a historic ruin in Elgin, Moray in north-east Scotland. A cathedral was first built on the present site in 1224 with an extensive rebuilding programme following a fire in 1270 and again in 1390. The cathedral was abandoned following the reformation and the roof removed in 1567 following which the cathedral fell into decay.[41] A large assemblage of 1,295 shards of glass is held in the collections of Elgin Museum were excavated in the mid 1970's and in 1996.

Thirty one samples for analysis were chosen to be a representative mixture of colour and shape, as well as having sufficient heart glass remaining for analysis. Analysis was carried out by p-XRF and SEM-EDS following the procedure by Kennedy and others.[42] The full details and results of the analysis will be published in a future paper.[43]

As expected all the samples are potash-lime-silica 'forest glass' composition. Potassium levels range from 11–20 wt.% K_2O, while calcium ranges from 12–28 wt.% CaO. Most samples had between 1–3 wt.% of sodium (Na_2O) present, 5–8 wt.% of magnesium (MgO) and 1–3 wt.% of aluminium (Al_2O_3). This is broadly consistent with work by others analysing European medieval glass and the composition is consistent with the typological dating of the 13th century.[44] Glass rich in potassium generally suggests a medieval glass composition from central continental Europe, and France or Germany would naturally be considered as potential origins of the glass.

A plot of CaO:K_2O ratios (figure 5) suggests that the samples can be separated into two groups and there is a clustering of colours within these groups. The majority of the samples have a CaO:K_2O ratio of between 0.8–1.5. This is consistent with a group of glass identified as Type III by Brill and Pongracz[45], which they suggest is a compositional type found in both English and French contexts from 1200–1400.

A smaller group has a CaO:K_2O ratio which is greater than 2. This suggests a 'wood-ash-lime' type of glass which is more typical of a German composition or possibly a

37 Longworth et al. 1982, 261.
38 Tennent et al. 1984, 133–50.
39 Graves 1985, 133.
40 Rauret et al. 1987, 249.
41 Fawcett 2001, 6.
42 Kennedy et al. 2013, 467.
43 Spencer et al. forthcoming.
44 Brill and Weintraub 1992, 143–8; Brill and Pongracz 2004, 115–44; Wedepohl and Simon 2010, 89–97.
45 Brill and Pongracz 2004, 119.

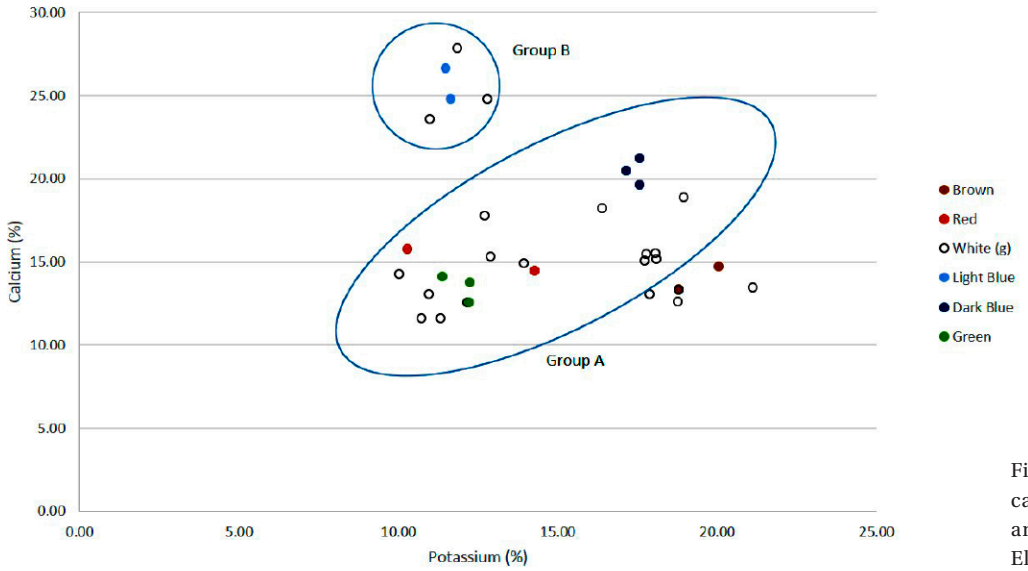

Fig. 5: Plot of potassium vs calcium for 31 glass fragments analysed by SEM-EDX from Elgin Cathedral. © author.

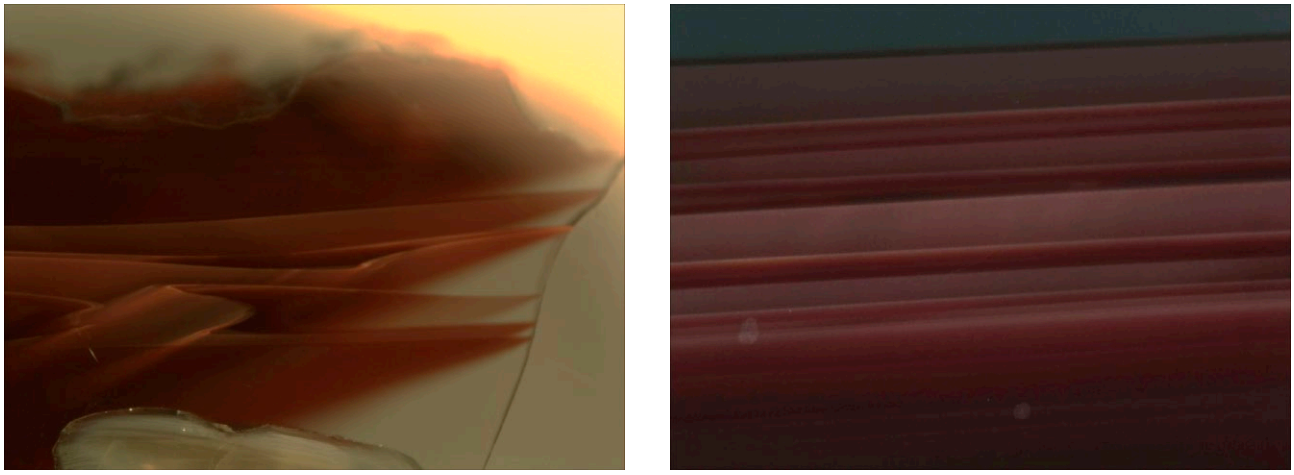

Fig. 6: Cross section of a sample of red glass from Elgin Cathedral showing the multi-layered red and white glass. © author.

French composition but made at a later date than the previous group.

A third possible group, includes the two fragments of brown glass. The two brown glass shards both have lower calcium and a much higher proportion of potassium compared to the other samples, having a CaO:K_2O ratio of only 0.7. The two brown glasses were also notable for their high concentration of phosphorous (>5 wt.% P_2O_5) and magnesium (5–7 wt.% MgO). This may suggest a French origin rather than a German one,[46] as glass from English and French sources often contained a greater proportion of phosphorous and magnesium than wood ash glass produced in Germany, due to the use of fern and bracken as the main alkali source.

The red glass falls into the first group with a CaO:K_2O ratio of 1.2 and with copper as the main colouring agent being present at 0.46 wt.%. When studied under an optical microscope (figure 6) it can be seen that the red glass is made from a series of striated glass layers according to the description of Spitzer-Aronson and Kunicki-Goldfinger and others.[47] 'Flashed' glass, where a single (or sometimes double) layer of red glass is on top of a clear sheet, is thought to have been in use from the late 14th century so the use of the multi-layered glass again suggests an earlier date. The predominant colouring agent of the dark/mid green glass is also copper, being present in concentrations between 3.96–4.97 wt.% CuO.

There are two different blue glass compositions present at Elgin. Two samples have a CaO:K_2O ratio of 1.2 and have around 0.12 wt.% cobalt (CoO) as a main colouring agent. Three other samples are lighter in colour and have less than half the amount of copper compared to the first group. This second group also has a much higher CaO:K_2O ratio of 2.5 and lower levels of magnesium and phosphorous. The difference in these two groups of blue glasses suggests they were made in different locations, possibly at different times. It may be that contrasting tones of blue were sourced from different specialist production centres when the windows were first installed, or that one blue represents a later repair or new window.

46 Wedepohl and Simon 2010, 96.
47 Spitzer-Aronson 1986, 672; Kunicki-Goldfinger et al. 2014, 66.

CONCLUSIONS

This paper has presented the start of a multidisciplinary research project to scientifically analyse Scottish medieval and post-medieval window glass. The initial results from the analysis of glass from Elgin Cathedral suggest that glass was imported from a number of different manufacturing locations in Europe in the 13th century, with different colours made in different locations.

Analysis is underway on nearly 200 samples of glass from twelve sites across Scotland using SEM-EDX. It is then planned to carry out trace element analysis using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS). Trace element analysis will be essential to be able to confirm differences observed in the main element compositions and some trace element concentrations are specific to the original raw materials of sand, alkali, lime and colourants.

The project on medieval ecclesiastical and monastic glass is being complemented by similar scientific research on window glass from late and post-medieval domestic sites.

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