ESTONIAN ACADEMY OF ARTS
Faculty of Art and Culture
Department of Cultural Heritage and Conservation

Jelizaveta Tsedenova

14TH CENTURY ENGLISH STAINED GLASS PANEL. ANALYSIS OF THE GLASS DETERIORATION AND CONSERVATION

BACHELOR THESIS

Supervisor: Prof. Dr. Joost Caen
(Artesis University College of Antwerp)

Antwerp 2012

CONTENTS

INTRODUCTION

In the Middle Ages the art of stained glass was flourishing. The windows of the churches were colourfully decorated. To fill in all the space of the windows in even poorer churches, less complicated motifs of decorations were used. Later the stained glass lost its position in the hierarchy of the arts. Today due to the aging and in some cases long term neglecting, the problem of deterioration of medieval stained glass panels arises.

In the central attention of current Bachelor Thesis is a panel that was part of a Medieval stained glass window. The aim is to create an art historical background and to do the research of the deterioration processes of medieval stained glass panels in order to work out best conservation approach.

Exact dating of the stained glass windows is very difficult except where there are definite historical records. In attempt to date the stained glass panel is introduced typical patterns of 14th century in English stained glass and brought out examples of already dated windows. The current panel has an acorn motif on it and because of that the foliage[1] in English stained glass of 14th century will be under closer observation.

Glass is usually considered as a chemically rather stable substance but in combination of aging and bad storage conditions, glass deteriorates. To choose the best conservation approach, it is crucial to know the type of deterioration the glass is suffering from. Next to the glass corrosion the observation of current case showed some signs of possibility of manganese staining. To indicate the specific deterioration it is needed to do the research.

The art historical part is based on English authors such as Baker, Dranke and Arnold. To get the information about manganese staining were studied articles of Schalm, Cagno, Watkinson and others, also a book “Conservation of Glass” by Davison. Illustrations for art historical part are mostly from Baker’s book (equivalents found from internet), the ones that are not mentioned in the illustration list are made by the author.

The first part of the Bachelor Thesis introduces the iconography and traditions of English stained glass in 14th century. To support the information about dating the panel next part talks about medieval glass making techniques. The deterioration of the glass is introduced, more precisely is described manganese staining. The last part shows the conservation of the current case. Additionally there is photo documentation and graphical documentation of the deterioration. The Bachelor Thesis is digitally added the CD.

[1] Here and further „foliage“ refers to herbal ornament painted on a stained glass window.

1. ART HISTORICAL ANALYSIS

1.1. English stained glass in the 14th century – Decorated[2]

With the 14th century commenced the most rapid period of evolution that the craft of glass painting has ever experienced. In the year 1300 traces of the early traditions still lingered; heavy colouring, small mosaic methods of glazing, crude drawing, primitive technique. Yet before 15th century style of Perpendicular glass, almost pictorial in treatment, light in colouring, of masterful design, and consummate craftsmanship, was to be seen everywhere throughout Western Europe. The whole history of Decorated glass, a style beautifully adapted to its material, is contained within that hundred years.[3] Developments in architecture and in glass techniques were two factors that shaped the most the character of stained glass during that period.[4]

Perhaps the greatest evolution affecting the change in the character was the use of silver stain. By this means it became possible to obtain two colours on one piece of glass, yellow on white, so that the white glass could be enriched with patterns in the new stain, and figures wearing crowns could have the crown included on the same piece of glass used for head.[5] It was also successfully used for a background grisaille and a foliage.

Stained glass motifs were also affected by the change of mental attitude of society. The fierce missionary zeal for the Faith, the mystic symbolism, has gone. The wonderful two hundred years which produced motifs of St. Bernard, St. Francis, St. Dominic, St. Louis and the Crusades, and which saw most of the great cathedrals built are over, and a reaction sets in. Churchmen are growing comfortable and apathetic, if not corrupt, and laymen are either uninterested in religion or critical. Money for windows was obtained from donators who "wrote in windows of their well deeds."[6]

With the religious motive thus weakened the artist seems to have interested himself chiefly in the technical side of his art. The lack of the underlying and unifying motive produces a shift of proportion in the parts. The canopies become much more important than the figures under them; narrative subjects become much more rare, and when they occur have none of the dramatic intensity of those of the past age. Instead there are an endless series of single figures

---

[2] Here and further "Decorated" refers to the stained glass style in England during 14th century.
[3] Dranke, M. A History on English Glass-Painting. London: T. W. Laurie, 1912, p. 21.
[4] Baker, J. English Stained glass. London: Thames and Hudson, 1960, p. 87.
[5] Ibid.
[6] Arnold, H. Stained Glass of the Middle Ages in England and France. London: A. & C. Black, 1913, p. 125–127.

of saints, without character and each in exactly the same affected attitude, like an elongated letter S.[7] (Fig. 5.)

In search of inspiration the artist turns to the study of nature and the literal reproduction of plant forms in ornament. In the figures too, although the attitudes are conventional the drawing of drapery is less so, and towards the end of the period the artist is tentatively feeling his way towards modelling.[8]

The subjects depicted on the windows can be classified generally into four categories: grisaille windows, figure or subject and canopy windows, single figure on quarry backgrounds and Jesse windows.[9] From the Decorated period an oak leaf and acorn pattern can be found on all these windows.

Grisaille, geometric or leaf patterns of regular design painted on to the white glass, become increasingly popular in England from the beginning of the thirteenth century as a means of decorating large windows at low cost and allowing more light into the body of the church. This combined with the development of silver stain, which introduced wide range of yellows into glass painting after c.1300, revolutionized the making of coloured windows and ensured their appearance even in humble churches.[10]

1.2. Foliage in the fourteenth century windows

During the early period of 14th century, the grisaille windows continued much as it was in the last years of 13th century, which means interlaced, leads, and coloured strap work, but with some differences. One of them was that the foliage was treated more naturalistically. It was not a sudden change, the earlier forms continuing for some few years into the new century. The plant forms used in these windows were recognizable as belonging to definite plants, the oak, vine, ivy, hawthorn and many others.[11]

The prevailing impression after careful examination of a series of Decorated windows is that they are full of foliage. To a great extent this is actually true, for grisaille, climbing borders, and flowing diaper work alike are all based more or less upon naturalistic forms. No attempt

[7] Arnold, p. 125–127.
[8] Arnold, p. 125–127.
[9] Baker, p. 88.
[10] Williamson, P. Medieval and Renaissance Stained Glass in the Victoria and Albert museum. London: V&A Publications, 2003, p. 136.
[11] Baker, p. 88.

is made to imitate the angularity proper to their growth though. The stems flow in the rounded curves but the leaves issuing from them are unmistakable.[12] (Fig. 1.)

The character of Decorated foliage bears unmistakable evidences of having been drawn from life. The painter still spaced his design upon the curves of early English foliage, but its conventional rotund trifoliations are gone. The Decorated craftsmen divided their allegiance: on the one hand they swore by geometrical curves, and on the other by naturalistic forms. They managed to compromise between the two by grafting their naturalism upon their geometry. Geometry underlies all their designs, foliage adorns them.[13]

In the simplest of these windows the only colour would be silver stain used on the floral forms, and the bands running parallel with two top sides of the quarry forming the interlacing pattern, but many were further enriched with shields of arms or small roundels. Panels with a figure or group of figures, depicting a scene from the Scriptures or life of a saint, would be set in the backgrounds[14] that curve around the central motive.[15]

Figure 1. Acorn and oak leaves on curved stem from a panel composed from different pieces.

[12] Dranke, p. 34.
[13] Ibid.
[14] Baker, p. 88.
[15] Arnold, p. 156.

1.3. Examples of oak leaves and acorns in the English stained glass

Figure 2. All Saint's Hawton, 14th century.

As can be seen on the photo the window is decorated with acorn and oak leaf pattern that is coloured using silver stain. The shape of the light is also similar to the piece under the treatment. [16]

[16]Southwell & Nottingham Church History Project http://www.nottsopenchurches.org.uk/Med.%20glass%20photos%20%20for%20web/Hawton/Hawton%20%2818%29%20w1000.jpg (11.11.11).

Figure 3. East Stoke St Oswald, 14th century.

In 19th century decaying remains of medieval glass were either replaced by a new copies, or rearranged into a patchwork window to make way for new commissions.[17] In this case can be seen that kind of situation and among all other pieces there are parts depicting acorns and oak leaves, decorated with silver stain. [18]

[17] Burman, P. ed.Treasures on the Earth. London: Donhead Publishing Ltd, 1994, p. 192.
[18]Southwell & Nottingham Church History Project
http://www.nottsopenchurches.org.uk/Med.%20glass%20photos%20%20for%20web/East%20Stoke/East%20Stoke%20%281%29%20w1000.jpg (11.11.11).

Figure 4. Acorn in the stained glass window in Saundby, Nottinghamshire.

Early 14th century side-shafting from a canopy, with a piece of oak trail behind it. [19]

[19] Vitrearum (Allan Barton)'s photostream. http://www.flickr.com/photos/vitrearum/4118061172/in/photostream/(11.11.11).

Figure 5. St Michael weighing a soul.

Eaton Bishop, Herefordshire, Parish Church of St Michael, East window, St Michael weighing a soul dates from 1317 – 1321. According to Sir Herbert Read in his book „English Stained Glass“ this is one of the earliest examples of the use of silver stain, and is probably of „Westminster“ school of glass painting. The figure of St Michael stands in the typical S pose so characteristic of that period. The figure is surrounded by a richly coloured, tall canopy, in the border of the panel acorns can be seen. [20]

[20] Baker, p. 96.

Figure 6. Cusped head of a light with oak grisaille. c. 1325.

Oak stems, some with acorns, are intertwined with trellis coloured in silver stain. Panel is currently in the Victoria and Albert Museum. [21]

[21]Official website of Victoria and Albert Museum http://www.vam.ac.uk/content/articles/e/english-stained-glass-1325-1520/ (27.11.11).

Figure 7. Merton College Chapel.

The windows in the chapel of Merton College, Oxford, are perhaps the earliest in which the design of Decorated period has taken a definite and typical form. A continuous flowing pattern of foliage—vine, oak, ivy, and fig—spreads through over the window from a central stem.[22]

At Boothby Pagnell parish church of St Andrew there are two windows, with medieval stained glass. Windows are combined from the remaining fragments of medieval glass dating to 1350–75. The glass was placed where can be seen now when church was restored in 1897. Fragments include head of a bishop, gabled roofs, seaweed and vine rinceau, trellised oak quarries, white with yellow stain.[23]

At Exeter Cathedral the choir windows were originally glazed in pairs, each displaying foliage from Decorated period readily identified as belonging to the oak, the hawthorn, and other familiar native trees.[24]

[22] Arnold, p. 153, 156.
[23] Hergin-Barens, P. Medieval Stained Glass of the Country of the Lincolnshire. Oxford: Oxford University Press, 1996, p. 38–39.
[24] Dranke, p. 34.

2. MATERIAL-TECHNICAL ANALYSIS

2.1. Glass cutting in the Middle Ages

Since the Middle Ages the process of the glass cutting has changed a lot. In the manual on glass making, painting and metalwork dating circa from 1100 by a monk under a pseudonym of Theophilus it is said: "Heat in the fire the dividing iron, which should be thin throughout, but thicker at the end. When it glows in the thick part apply it to the glass which you wish to divide, and presently the commencement of a small fissure will appear. If, however, the glass be hard, wet it with saliva, with your finger, in the spot where you place the iron; being instantly cracked, draw the iron along where you wish to divide, and it follows by the fissure. All the portions being thus divided, take the riesel iron, which is palm in length, and equalize the parts."[25]

To break it in desired shape was used a thermal shock to create tension in the glass. Thought being rather accurate method, most of the times the shape of the glass was not all correct and had to be perfected. An extra glass had to be grozed away which means biting away small fragments from the edge of the piece of glass with a pair of special pliers called riesel iron.[26] After the grozing the edges of the piece obtained a characteristic shape that indicates the use of this specific technique.

That method of working had influence the shape of the glass and on the overall shape of the design. It was more simple and straightforward. In the early 16th century the diamond for cutting glass came into use. Physical tension created by the diamond cutter allowed to shape the glass pieces into different and more complex forms.[27]

2.2. Silver stain

In the beginning of the 14th century a silver stain as a glass colouring method was introduced[28] in England though it was known before that time in other countries. Since that time the technique has a great influence on the art of glass paining.

[25]Theophilus. Encylopedia of Christian Art of the Eleventh Century. Hendrie, R. tran. London: John Murray, 1847, p. 139.
[26] Duthie, A. L. Decorative Glass Processes. New York: Dover Publication, 1982, p. 260.
[27] Amillard-Nouger, A., Rameau-Monpouillan,C. Le Vitrail. Image et Atmosphere. Geneve: Aubanel, 2005, p. 34.
[28] Davison, S. Conservation and Restoration of Glass. London: Butterworth, Heinemann, 2003, p. 133.

When an oxide of silver is applied to glass and fired in kiln (oven used to fire glass) the heat triggers chemical reaction coaxing ions of silver to migrate into the glass. The result is that the glass is permanently stained a transparent yellow colour.[29] Silver penetrates the surface of the glass and produces a perfectly transparent colour with no opaque layer upon the surface.[30] The effect of silver stain depends on the amount of stain applied and the number of applications – the temperature at which it is fired and the chemical composition of the glass.[31]

Stain is always applied to the back of the glass. If it be applied to the same side as the colour the fumes which it gives off in firing will interfere with the fusing of the colour and prevent its becoming fixed.[32]

Silver stain fired on to glass surface can either play a protective role, or promote localized deterioration of the underlying glass. The paint is generally more durable than the glass so that, after weathering has occurred, the painted line-work may be raised above the rest of the surface of the glass. Less frequently it can have the reverse effect, and marked deterioration has occurred where the glass had been painted.[33]

2.3. Deterioration of the glass

Iridescence is a phenomenon when the surface of the glass has rainbow shine to it. Sometimes it occurs alone and sometimes it is associated with other types of weathering. The thickness of the surface layers containing a concentration of metal oxides (in the order of hundreds of nanometres) causes light interference, resulting in the vivid iridescent colours, such as gold, purple and pink. When found alone, it is first visible in filmy patches, and it may then become abraded in powdery form. If undisturbed, the iridescence may develop into a thick layer, which may flake away. Thick layers of glass flaking away may eventually weaken the glass so severely that it collapses entirely.[34] Iridescence of the glass matrix is first step in glass corrosion.

Atmospheric pollution in the form of the chemicals from the surrounding water or air, and accumulating particular matter, cause deterioration of glass. The chemical processes associated with the deterioration of historic glass arise as the result of the internal composition

---

[29] Leap, K. Silver Stain. San Francisco: Blurb, 2010, p. 7.
[30] Duthie, p. 78.
[31] Davison, p. 133.
[32] Duthie, p. 95.
[33] Davison, p. 192.
[34] Davison, p. 183.

of the glass being attacked on a molecular level by external forces, principally involving water. When a glass reacts with water chemical changes occur at the glass surface, which then progress into the body.[35]

The surface of the glass is constantly in contact with the external environment that consists of different chemicals. The structure of the glass network can be affected by the chemicals from the environment. The most obvious reason for glass decay is present surrounding moisture that chemically reacts with the surface of the glass. Usually chemical deterioration is described as a combination of three simultaneous processes.[36]

The first step is the penetration of molecular water into the glass. During this process of molecular diffusion, the silicate network goes through a structural transformation. This transformation allows later ion exchange. Ion exchange is based on the substitution of the mobile cations from the glass with protons from the surrounding environment. The mobility of cations depends on their charge, their size and the composition of the healthy glass. In this process heavier particles (cations) are replaced by lighter ones (protons). After that exchange the volume of the leached layer remains similar, but the density of the leached layer becomes smaller than of a healthy glass.[37]

When the water is stuck in the cracks of the glass surface, the pH will increase as a result. When the pH values exceed the value of 9, hydroxyl ions in solution will attack the silicate network. As in the structure very few cations are left, the network of Si–O is weakened and a leached layer is formed.[38]

The leached layer can occure in the form of a pit or as a lamellar structure. The pit deterioration occurs when the cations are leached out locally and form an individual point that is more receptive to corrosion. With lamellar deterioration the glass surface is more or less equally influenced by the environment and form a layer that gradually grows inwards.[39]

In this so called leached layer glass decay can develop further. One phnomenon of further and more complex glass corrosion is the occurance of manganese staining that can be traced in leached layers or lamellae of the glass.

---

35 Davison, p. 182–183.
36 Schalm, O., Proost, K., De Vis, K., Cagno, S., Janssens, K., Mees, F., Jacobs P., and Caen, J. Manganese staining of archaeological glass: the characterization of Mn-rich inclusions in leached layers and a hypothesis of its formation. – Archaeometry 2011, 53, p. 103–122. doi: 10.1111/j.1475-4754.2010.00534.x.
37 Ibid.
38Ibid.
39 Weber, L. Examination and removal of staining from Archaeological Glass. Diploma Thesis Submitted for the Degree of Konsevierung und Restaurierung von Archäologischen, Ethnologischen und Kunsthandwerklichten Objekten,Stuttgart: Staatliche Akademie der Bildenden Künste,- 2005, p. 13.

2.4. Manganese staining

Historic glasses contain usually a small amount of manganese oxide (0,4–0,8%)[40]. Most of this manganese is present as the colourless Mn(II), while a small fraction may exist as the strongly coloured Mn(III) that gives glass a purple hue. Higher oxidation states are normally not present in glass. Furthermore, there could have been two different ways how Mn was introduced into the glass batch: 1) as an impurity in one of the raw materials, such as wood ash and 2) as a deliberate addition of pyrolusite[41], which is a mineral that consists mainly of manganese dioxide[42], to the liquid batch, in order to decolourize the glass. In the liquid glass, the higher oxidation states of manganese transforms the colouring substance Fe(II) into the less colouring Fe(III).[43]

The Mn(III) that gives the glass a purple tint is usually there deliberately but can be also formed spontaneously. If the colourless glass contains Mn(II) it can change colour. Being exposed to the sunlight can cause oxidation of Mn (II) into Mn(III) which makes glass look purple. This phenomenon is called solarisation.[44]

Manganese rich corrosion forms black or brown staining in the glass. It is one of the most disfiguring phenomenon that can effect as well archaeological glass as stained glass windows. Due to Mn-staining glass can becomes partly or fully blacked or browned and loses its transparency.[45]

Manganese is a chemical element which has long been used as a colouring or a bleaching ingredient in the glass industry. Its existence at various oxidation states is at the origin of a large variety of colours. This colour can evolve according to environmental parameters such as UV radiations, the atmospheric pollution or even biochemical attack[46]. In some ancient stained glass windows, the simultaneous presence of manganese and iron, coupled with the

---

[40] Cagno, S., Nuyts, G., Bugani, S., De Vis, K., Schalm, O., Caen, J., Helfen, L., Cotte, M., Reischig, P., Janssens, K. Evaluation of manganese-bodies removal in historical stained glass windows *via* SR-μ-XANES/XRF and SR-μ-CT. – Journal of Analytical Atomic Spectrometry 2011, 26, p. 2442–2451. DOI: 10.1039/C1JA10204D.

[41] Schalm, O. et al.

[42] Enghag, P. Encyclopedia of the Elements. Weinheim: Wiley-VCH, 2004, p. 636.

[43] Schalm, O. et al.

[44] Ibid.

[45] Cagno, S. et al.

[46] Orial, G., Warscheid, T., Bousta, F., Loisel, C. Incidence bactérienne dans les phénomènes de brunissement des vitraux anciens, – L'Actualité Chimique 2007, 312– 313, p. 34– 39.

alteration by water and micro-organisms, can induce a browning and, consequently, a loss of transparency in stained glass windows.[47]

The dark colour that is caused by Mn(IV) is restricted to the leached layers and is never present in the original, unaffected parts of the glass. This can be seen on the images of a cross-section of the samples that were studied for many researches on Mn-staining (Cagno (2011), Schalm (2011), Watkinson (2005), Weber (2005)). For buried archaeological glass, two types of manganese-rich inclusions are distinguishable: dark inclusions in the low-density lamellae of stratified leached layers and in cracks.[48] (Fig. 8.)

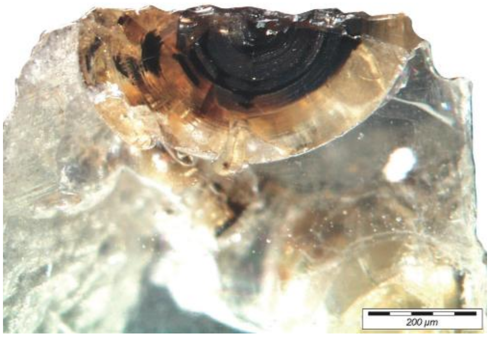


Figure 8. An optical image of a deteriorated region in a cross-sectioned 15th century sample excavated in Raversijd. In this sample, Mn-rich inclusions can be found between the lamellae of the stratified leached layer.

To detect manganese and other components in the glass Energy Dispersive X-ray Analysis (EDX) and Scanning Electron Microscopy (SEM) can be used. EDX obtains a localized chemical analysis of a sample that is under examination. It can detect all elements from atomic number 4 (Be) to 92(U). EDX uses the X-ray spectrum emitted by a solid sample. In addition to chemical composition it can determine the concentration of elements by measuring line intensities in the sample and for the same elements in calibration Standards of known composition. [49]

In order to produce magnified images with SEM the electron beam is focused into a fine probe-, which is scanned across the surface. Each point of the sample that is struck by the accelerated electrons emits a signal as an electromagnetic radiation. Selected portions of radiation are collected by a detector and the resulting signal is amplified and displayed on a monitor[50]. Though SEM is primarily designed for producing electron images, it can also be used in combination of EDX for element mapping.[51] A computer can sort out different chemical elements and display them as a combination of different greys. As for the human

[47] Cagno, S. et al.
[48] Schalm, O. et al.
[49] University of California Riverside. Central Facility for Advanced Microscopy and Microanalysis. Manuals. http://micron.ucr.edu/public/manuals/EDS-intro.pdf (30.03.12).
[50] University of California Riverside. Central Facility for Advanced Microscopy and Microanalysis. Manuals. http://micron.ucr.edu/public/manuals/Sem-intro.pdf (30.03.12).
[51] http://micron.ucr.edu/public/manuals/EDS-intro.pdf (30.03.12).

eye it is difficult to see the slight variation in colour, it is possible to program the computer to show different chemical elements separately.

The researches concerning Mn-staining reveal that other elements and materials besides manganese compounds can be associated with brown staining of the glass. As will be explaned:

a) The combination of Fe and Mn
b) The combination of Si, K, Cl and S
c) The combination of S, Fe, Si and Al

For example tests carried out by L. Weber et al. (2005) for an article about archaeological glass staining showed interesting results. Under the light microscope the damage of the samples from *Frankfurt* resembled Mn-staining but the SEM analysis of stained glass revealed that manganese was not responsible for staining. A slight enrichment of iron was detected as well as a significant sulphur presence. Potassium, calcium and sulphur had accumulated in similar lines. Silicon was strongly enriched in the corroded area, which emphasises the extensive corrosion.[52]

As another example from the same research can be named a *potash glass with high calcium content*. The glass was locally covered by star-shaped red-brown to yellow-brown translucent staining. The staining was clearly defined as localised star-shaped corrosion that reached approximately 400 μm into the sound bulk glass. EDX elemental mapping did not show the presence of manganese in this type of staining. Both silicon (silica enrichment) and aluminium network formers were enriched. While all the alkalis and manganese were leached out as compared to the bulk glass composition. Within the star cross-section both sulphur and iron, which was unevenly distributed, were present.[53]

Samples from Stafford Castle appear black-brown stained and opaque while wet. In cross-section black staining was distributed along cracks and lamellae resulting in a feathers staining pattern. EDX mapping revealed manganese in all stained areas. This coincided with iron in most cases. It was therefore assumed that these samples may be considered as a typical ‘manganese staining’.[54]

[52] Weber, L., Eggert, G., Watkinson, D. A Closer Look at Brown Staining on Archaeological Glass. Preprints Nova Gorica 2007, ICOM. p. 35–45.
[53] Ibid.
[54] Ibid.

The origin of the manganese concentrated in a corroded layer can be explained in two ways. If 1 mm^2 of healthy glass contains less manganese then the same amount of the corroded glass, it is very likely that the manganese can be introduced from the environment. In the opposite case the manganese should be from glass itself.[55]

To determine if it is possible that manganese that causes darkening of the glass could come from the environment was made a research by D. Watkinson et al. (2005). For that were made experiments with the expectation that the manganese can enter glass from the external environment. Before the experiments the surface of the samples was scratched and damaged. That was done because the Mn-staining has been traced only in damaged part of the glass where the wholeness of the glass had been disrupted and never in healthy bulk glass. [56]

Manganese can enter via cracks and capillaries, as the part of the process of the ion exchange during glass deterioration.[57] If there is also water and oxygen, originally Mn(II) can be oxidized into Mn(IV) that causes the discolouration.

The test results of Watkinson showed that glass put into the manganese solutions developed dark brown staining and the solution pH changed from its initial value of 4 to 8, due to leashing of alkali from the glass into aqueous test environment. With that result can be assumed that one of the reasons for the Mn-staining can be the manganese that enters from environment.[58]

Main purpose of the conservator is to treat the object minimising further damage and decay of the object. First choices of cleaning solutions are usually deionised water and/or ethanol. In case of discolouration of the glass neither of the solvents cause any visible change in glass appearance. In order to treat staining of the glass that has reached into surface, it is necessary to use more aggressive approaches.

To treat the historical glass affected by manganese staining have been used solutions of different reducing and chelating agents at various concentrations: hydroxylamine hydrochloride, hydroquinone, citric acid, potassium iodide and EDTA. However, the most commonly used products are hydrazine and commercial products containing hydrazine and hydroxylamine hydrochloride. When these products are applied to the leached layer, in a rather short time (*e.g.*, for 1–2 days) the brown stains disappear and leached layers obtain a

---

[55] Schalm, O. et al.
[56] Watkinson, D., Weber, L. and Anheuser, K. Staining of archaeological glass from manganese-rich environments. – Archaeometry 2005, 47, p. 69–82. doi: 10.1111/j.1475-4754.2005.00188.x
[57] Schalm, O. et al.
[58] Watkinson, D. et al.

semi-transparent, whitish look. The possibility exists that the Mn-staining will gradually reappear due to spontaneous reoxidation. On the other hand, if all or most of the manganese is dissolved and removed from the glass it can not influence the glass. But as the surface of the glass is already damaged it is possible that if introduced from the environment, manganese can cause the staining again.[59]

In the frame of the Diploma Thesis of L. G. Weber (2005) several experimental tests were carried out in order to see how different discolouring agents effect Mn-staining. According to those experiments citric acid removed all staining and produced translucent result. First edges of the samples changed to orange, then yellow and finally to white. The de-colouration process moved inwards. According to the EDX mapping the Mn enrichment was not present anymore.[60]

Use of hydroxylamine hydrochloride as manganese staining removal method was also closely monitored. When the treatment was stopped halfway, the sample had gone from black to orange. Depending on the duration of the treatment samples became yellow or even transparent. The orange sample went through EDX mapping that revealed some traces of the Mn, Fe and slight S enrichment[61] which means that these chemicals are responsible for the colouration of the glass.

The results revealed that the hydrochloride treatment is effective, but also that it has a number of unwanted side effects. Leaching damage is inflicted to the original glass by the reducing solution. Previously non-corroded surfaces develop leached layers and the dimensions of the cracks present in the historical glass are expanded by the exposure to the aqueous solution. This effect is proportional with time: after 270 minutes a 25% increase of the leached layer volume was registered. The fact that such damage takes place was not surprising, taking into account the nature of the treatment. However, considering that these types of solutions are used in restoration practice, some precautions should be taken. The optimal time and solution concentration and alternative application methods of solution were introduced.[62]

As a final conclusion, it can be said that the glass pieces that seem to have very similar symptoms referring to Mn-staining can be easily misdiagnosed. There are other mechanisms colouring leached layer like Fe or Al. The treatment that is meant to resolve the problem of Mn-staining has next to its cleaning properties also very considerable side-effects that damage

[59] Cagno, S. et al.
[60] Weber, L. Examination and Removal of Staining from Archaeological Glass, p. 94.
[61] Ibid, 96.
[62] Cagno, S. et al.

the glass. At the same time the results of some researches showed that the results of cleaning may not last for long and after some time glass obtains same defect as before the treatment.

In order not to do even more harm that the time has already done, it is highly important to do analysis to make sure that manganese is the component that is causing the staining. If glass is wrongly treated it might do much more harm to it than good.

3. *MOUCHETTE*-SHAPED PANEL

3.1. Background information

Current Bachelor Thesis is observing the *mouchette*-shaped panel. It belongs at the present moment to the private collection of Prof. Dr. Joost Caen. It was purchased in an antique shop in England and since then it has been stored between wooden plate and cardboard that is padded with bubble wrap (Fig. 9).

Figure 9. Storage of the panel.

4.2. Description

Most likely the panel used to be a part of an upper section (light) of a Gothic window in English church. The circle and its subdivisions, or *mouchettes* (Fig. 10.) provided the basic forms of Gothic tracery.[63] During the academic year 2011/2012 the stained glass was taken to the Glass Conservation Studio of Artesis University College of Antwerp for the observation and conservation.

The stained glass panel is in the shape of a *mouchette*. In the centre of the panel is a yellow circle. It is surrounded by another circle that is parted in seven and is formed from a blue glass. After the observation can be seen that the inner circle is not part of an original panel. That can be concluded because circle is smaller than the surrounding circle created by the rest of the panel. Extra space is filled with lead.

[63] Wood, D. ed. Stained Glass. London: Mitchell Beazley Publishers Limited, 1976, p. 32.

Next section depicts four acorns each with a stem and two leaves on a white glass. Acorn and it's leaves that is closer to the tail is coloured with silver stain. All the acorns are facing away from the middle part. In the piece no. 12[64], there is one piece of glass that is mismatching the rest of the pattern. As the colour and thickness of the glass is different from the rest of the panel it is possible that the whole fragment no. 12 is added later.

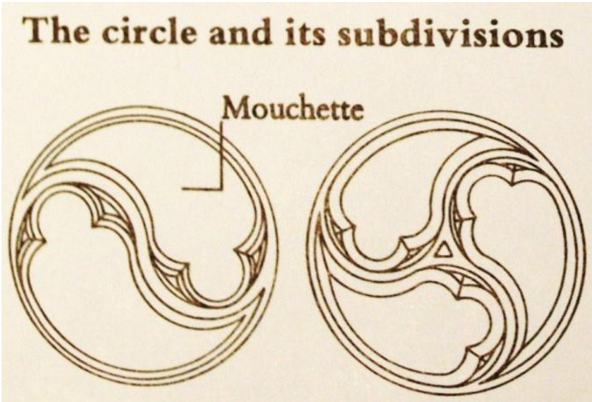


Figure 10. *Mouchette.*

The external part has two border lines – one heavy another light. During last releading of the panel, two pieces (no. 4 and no. 7) have been installed upside down.

Condition. The panel is in very poor condition. It is covered with not very thick coat of dirt. Most of the glass pieces have corrosion on both sides. Depending on the piece it is in a different stage of development. Some of the pieces have lost their transparency and are browned. The paint is relatively well preserved, it has faded only on the fragment nr 11. All pieces of the panel are cracked, except for the piece nr 7. Some of the fragments are lead together, some have a supporting bit of lead on the crack. At the same time there are many cracks that haven't been repaired.

Three different types of lead can be observed. Middle part has lead that is more dark and round. Most of the rest of the panel has the same lead. Third type of the lead is used to surround the panel, do some minor repairs and fixate the middle circle in place. Though the panel is surrounded by the new lead, older one is still underneath it. On the top of the panel can be seen some copper wire that probably was placed there as the mean for exhibiting.

More detailed description of the panel's cracks, corrosion and lead condition and typology can be observed in the graphical documentation.

Dating. Exact dating of this panel is very complicated but approximate suggestion can be made. By comparing it to the other stained glass panels that depict similar patterns and have more precise dating it is possible to make an assumption that it dates back to the first half of the 14th century.

[64] For the numbers of pieces, see Fig. 5 in Annexes.

3.3. Studies

Observation. Careful observation under direct and transmitted light shows that most of the glass has signs of deterioration. Some of the pieces have bigger or smaller craters on the surface which indicates the corrosion of the glass. With the transmitted light can be seen that there are pieces that are browned and have lost their transparency. This is a typical symptom of the glass with a manganese staining, but for more accurate data is needed further examination.

Observation of lead (Fig. 11.) shows that it has been made by milling and thus can not be medieval, which means that all the panel has been re-leaded. Only milled lead has marks of mill's teeth inside. The majority of British stained glass windows were restored and re-leaded during the 19th century.[65]

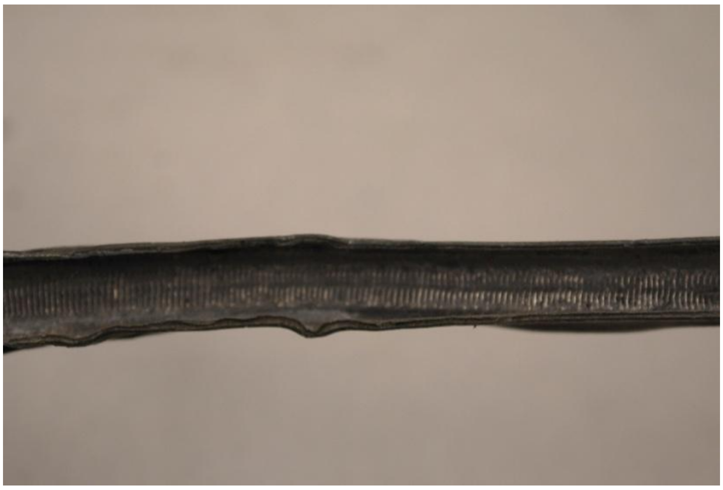


Figure 11. Fragment of lead with signs of milling.

[65] Burman, p. 195.

Microscopic studies. ***Detorioration of surface layer.*** Surface of the glass was examined under light microscope with direct and transmitted light. Under the microscope can be seen the extent of the deterioration, so the least damaging cleaning method can be chosen.

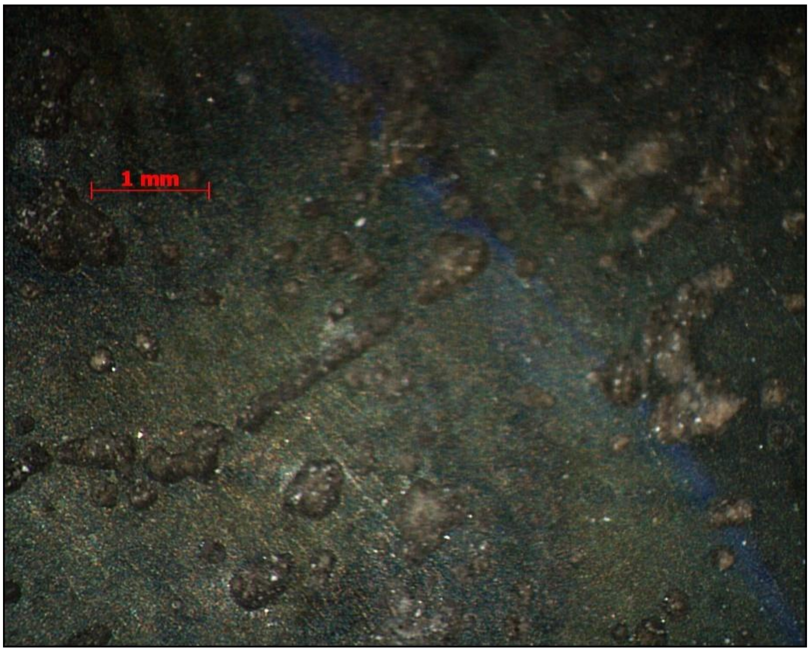


Figure 12. Deep pit corrosion 2,5x magnification.

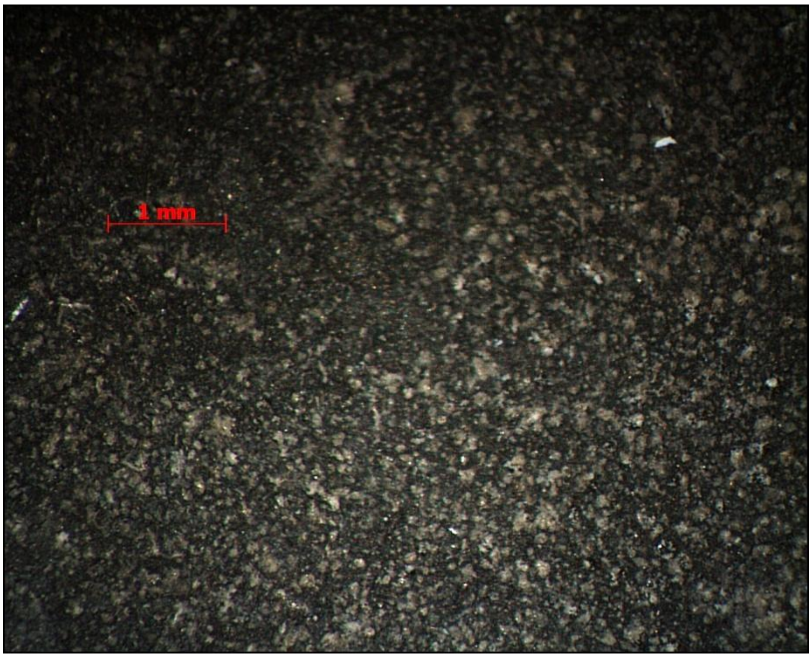


Figure 13. Closely placed pit corrosion that in transmitted light fog up the glass. 2,5x magnification.

Microscopic studies. ***Possibility of Mn-staining.*** Surface of the glass was examined in a transmitted light and samples of the glass cross-section were taken to see if it has a Mn-staining. On the image of cross-section can be seen a deterioration layer and among it some halation that may refer to Mn-staining. Even though both, surface and cross-section, examination seem to be similar to Mn-staining, further research under SEM is needed.

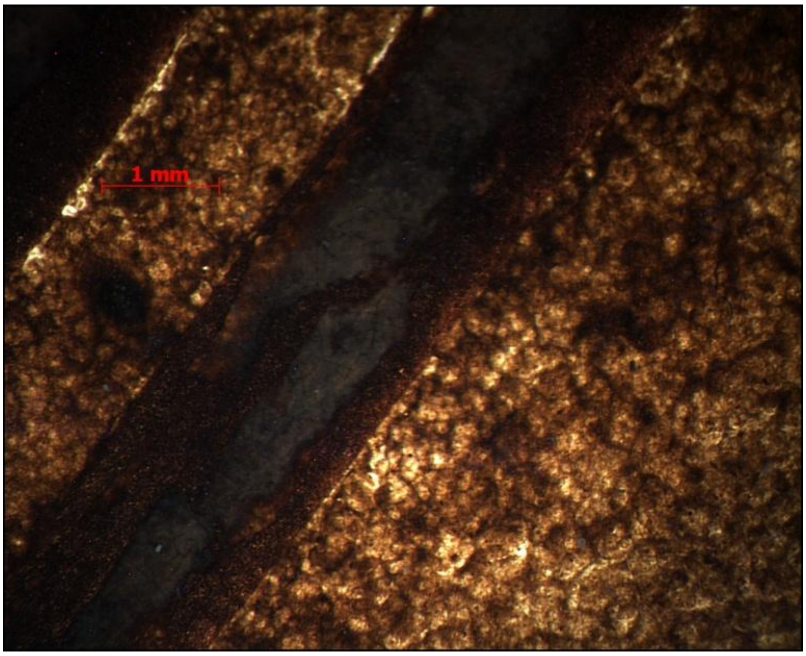


Figure 14. Edge piece nr 7 with the signs of browning under transmitted light. 2,5x magnification.

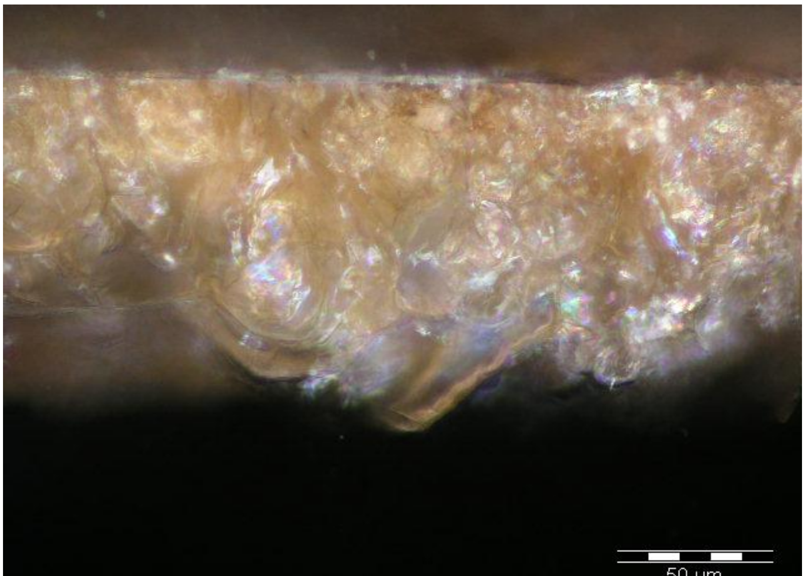


Figure 15. Cross-section of a piece nr 7, 500x magnification, dark field.

3.4. Treatment pruposal and conservation plan

<u>Cleaning</u>

After dismanteling the panel could be decided the method of cleaning the pieces. Though the surface of the glass looks rather dirty, it is due to the corrosion or staining than the superficial dirt. Trying to make the glass translucent by using strong chemicals or physical force would be direct destruction of the historical substance and is ruled out.

All the edges of the pieces are covered with the leftovers of cementing that has to be cleaned. The consequences of the removal of the cement was observed under the light microscope. Solo use of the scalpel leaves considerable damage to the surface of the glass. To reduce the damage it is necessary to soften the cement. For that purpose was tested ethanol, as it did not work was tested dimethylformamide (DMF).

DMF softened the cement to the degree that it was very easily removed with scalpel. It is chosen to remove the cement because excessive use of mechanical force would cause too much damage to the glass.

<u>Bonding</u>

Each broken piece is being carefully observed and analysed to decide how it should be resembled. The decision depends on how well broken pieces matched together.

The previous conservation was done using lead straps to hold broken pieces in place. This time it is decided to use in most cases as a bonding material epoxy Araldite 2020 in order to restore the original division of the pieces as much as possible. Araldite 2020 is very appropriate as if used properly it bonds the broken glass for a long time and at the same time created bond is reversible. Though it yellows over the decades, in this case it has no impact because the original pieces are very dark and corroded.

<u>Reconstruction</u>

It is decided to reconstruct piece nr 12. The piece is in a central part of the panel and reconstructing it would make the general look of the panel lighter and more close to the original. Though the piece is broken into fourteen pieces and in some parts reassembled with lead, most of the edges match each other perfectly. There is one piece that does not match the original and therefore will be removed. It is decided to replace it with a new piece that will be made slightly lighter in order to make it more distinguishable that it was added later by conservator.

Retouching

The pieces that were bonded had to be retouched to create the balance of the impression. To retouch stained glass as a bonding material is usually used Paraloid B72 that is dissolved in diacetone alcohol. Inorganic pigments were chosen over industrial glass colours as they are more lightproof and does not leave shiny surface.

Releading

Releading has two problems. First is that after the time and probably many previous releadings while reassembling in lead the pieces are not matching each other perfectly anymore. There is a potential of many big gaps between lead and glass. The owner wants the general impression of the panel to be closer to original which means it has to have much lighter general look to it than created by the person who treated it previously. It is decided to use 5 mm lead in the central part, using wider lead as going outwards. Wider lead of 8 mm and 10 mm on the outer lining will have to be used to cover bigger gaps between lead and glass. If there will be still gaps left, they should be filled with cement. Piece no. 7 was flipped and will be turned right way. Piece no. 4 was also flipped but it will stay that way as other way it would be impossible to reassemble the panel.

The central part of the panel is probably originally not from this panel and is smaller than the circle formed by the rest of the pieces. Previously it was solved by filling the excess space with extra large lead. That approach made the general impression of the panel rather heavy. The addition of the circle was done later than the panel itself and so it is decided to choose different approach. The space between central circle and the rest of the panel will be filled with glass. To harmonize the addition with the panel is chosen plain 17th century glass with some corrosion. That kind of approach allows to created lightness and at the same time it does not disturb general impression of the panel.

Motivation

The panel has art historical value as it is a good example of 14^{th} century stained glass art in England. It is has also a research value as there is a corrosion layer and possibly manganese staining which makes it interesting example of glass deterioration. Because of that it needs to be preserved for the next generation. The purpose of conservation treatment of the stained glass panel in mind is to minimise the increase of the deterioration of the glass, restore the wholeness of the pieces as much as possible and give the panel as an integral whole lighter impression. The panel has to be the properly supported to ensure the safety of the panel during its exposition. Also it is necessary to keep in mind preventive and passive conservation after the treatment.

In the Corpus Vitrearum's Guidelines for Conservation and Restoration of Stained Glass is stated: "Any treatment of the glass surface and its decoration must be preceded by a thorough examination to identify the original materials, their alteration phenomena and products, as well as any foreign accretions. As a general rule, corrosion products are considered to be evidence of the material history of the glass. The main objective in the treatment of the surface is to conserve the glass and not to recover transparency through removal of corrosion products and deposits. When called for, cleaning should always be undertaken in a localized, well-controlled manner and with full consideration of the risks posed by the methods and materials employed. Soaking or poulticing of a whole panel or an entire piece of glass must be avoided."[66] Corrosion layer acts as a protection coat for the rest of the glass and removal of it exposes „healthy" but already fragile glass surface to the environment and decay continues.

[66]Official website of Corpus Vitrearum. http://www.cvma.ac.uk/conserv/guidelines.html (23.11.2011).

Conservation plan

1. **Documentation before the treatment.**

   Photographing, measuring, numerating the pieces, graphical documentation of the damage.

2. **Dismantling the panel.**
3. **Preliminary studies.**

   Cleaning tests, discussion of reconstructing the pieces and reassembling the panel.

4. **Microscopic studies.**

   Studies under light microscope, taking samples and studying the cross section.

5. **Cleaning the pieces.**
6. **Reconstructing piece no. 12.**
7. **Bonding.**
8. **Retouching.**
9. **Leading pieces back together.**
10. **Cementing the panel.**
11. **Final documentation.**

3.5. Conservation

Dismantling (Fig. 16.) of the panel showed that it was cemented. One of the leads used to repair the piece nr 12 didn't have a core. Lead supporting crack in the piece nr 10 was heavily cemented to stay in place. After dismantling edges of the glass pieces can be seen that they show evident signs of use of the riesel iron (Fig. 17.).

Figure 16. Dismantling of the panel.

Figure 17. Grozed edge of the piece of glass.

Figure 18. Dismantled panel.

For the **cleaning** the surface dirt from the pieces was chosen solution of deionised water and ethanol (75/25). Ethanol was added to solution to make it evaporate quicker so that it would cause the least further damage to the glass.

To soften the cement was used DMF. To ensure the personal protection the procedure was carried out under the suction pipe, with a protective mask and gloves.

The edges of the each piece were covered with cotton compress with DMF and wrapped in plastic to prevent the solution from evaporating. It was left like that for an hour to let the solution work (Fig 19.). After an hour the piece was taken out of the wrap and the softened cement was removed with a scalpel (Fig. 20.).

Figure 19. Piece in a DMF wrap.

Figure 20. Removal of the cement.

As a first step to **reconstruct the piece no. 12** was determined exact shape of the piece. It was done by combining all the fragments together and making a drawing on a paper (Fig. 21).

Figure 21. Planning the shape of the piece no. 12.

Figure 22. Bonding two sides of the piece.

Fragments of the left and right side of the piece were bonded with epoxy Araldite 2020, leaving out the fragment that had to be reconstructed. Smaller gaps were filled with the epoxy. (Fig 22.)

Missing fragment was cut out from the glass with as similar shade to original as possible. Colouring of the fragment was done using grisaille paints and later fixated by baking in the oven.

New infill was bonded with the rest of the piece using Araldite 2020. As a final step of reconstruction the transparent parts that were created by epoxy were covered with retouch.

Figure 23. Making the infill.

Figure 24. Final result.

Pieces were **bonded** with the epoxy Araldite 2020. Edges of the fragments were cleaned thoroughly with acetone and fixed in place with a transparent scotch tape. Pieces were placed on a glass wrapped in plastic, to insure that the pieces are not going to be stuck to the base, pieces of dental wax were placed in between (Figure 25.). After the curing period of 24 hours the scotch tape and the excess of the glue was gently removed with the scalpel.

The lead strap was left to support pieces no. 1, 3, 8, 10 and 13.

Figure 25. Bonding the pieces.

After bonding pieces had to be **retouched**. For that was used inorganic pigments with Paraloid B72. dissolved in diacetonealcohol. Retouches covered transparent parts that were created with bonding.

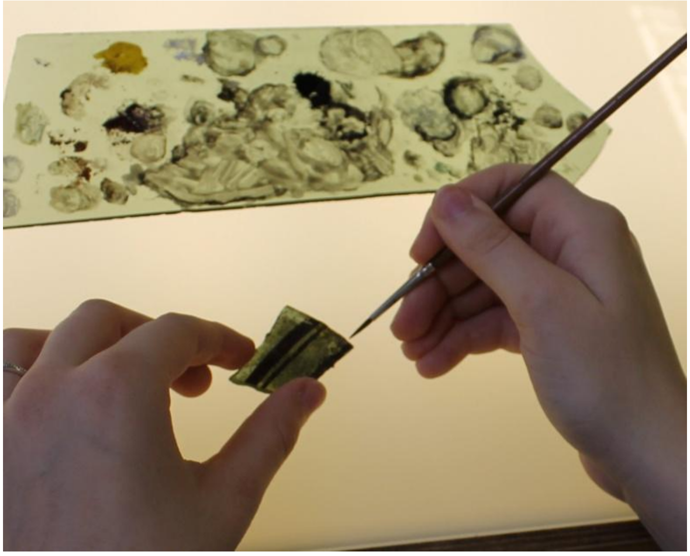


Figure 26. Retouching.

Before leading pieces for the central part were cut out from 17th century glass.

Leading was done by using 5 mm, 8 mm and 10 mm lead. Pieces put together with lead and secured in place with nails. After reassembling the edges of the lead were pushed down to make soldering more efficient. Meeting points of the lead were soldered with soldering iron. To solder the lead with tin it is necessary to use an oliena, which prevents oxidation of the metal during the soldering process.

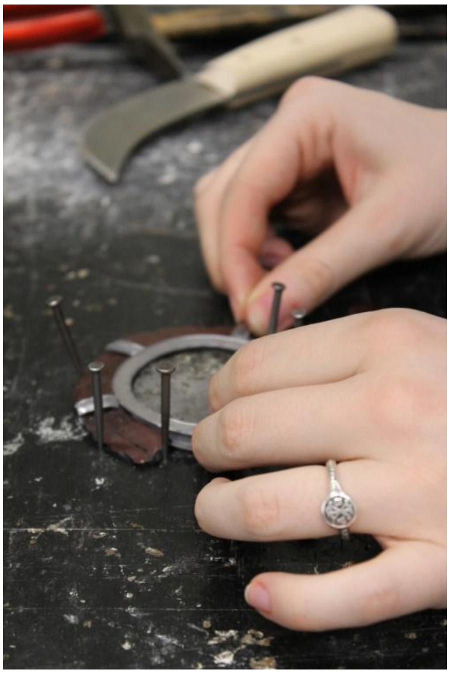


Figure 27. Securing the glass with nails before soldering.

Figure 28. Pushing down the edges of the lead.

After the panel was soldered it could be seen that there were still some gaps between the glass and the lead. To fill the gaps was used a cement. It was made by mixing powdered chalk and linen seed oil. In order to camouflage the cement and make it grey as lead, little amount of black pigment was added. Cement was applied with fingers as it gave the full control of the process and minimized the unnecessary impact with the panel. Leftovers of cement were removed with water ethanol 50/50 solution.

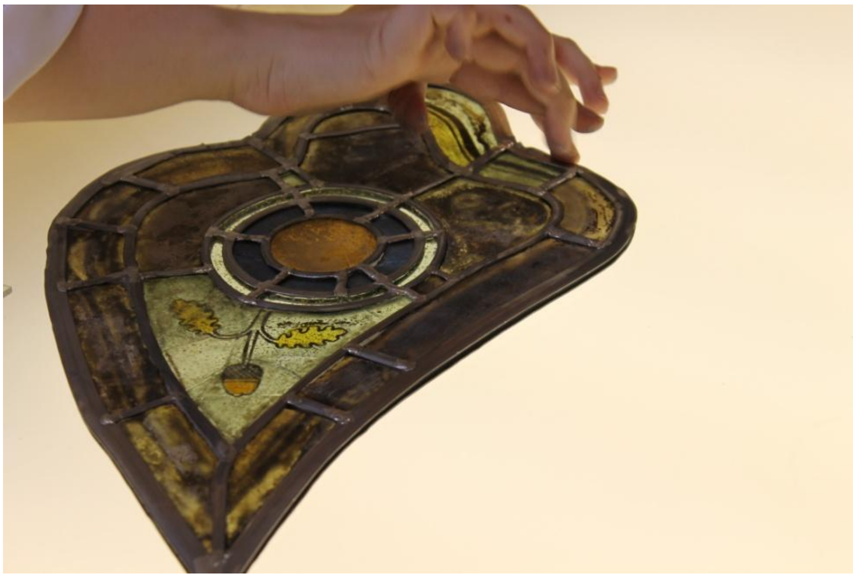


Figure 29. Cementing the panel.

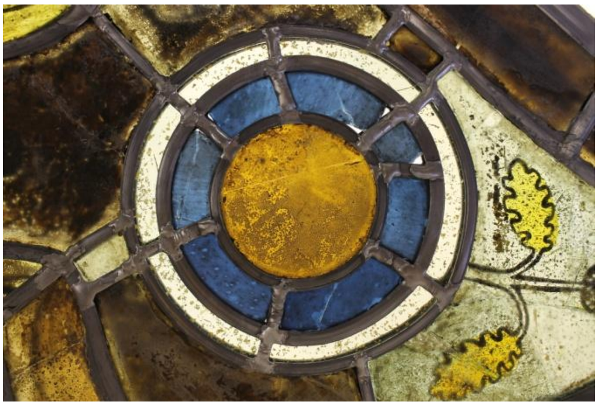


Figure 30. Detail of the panel before and after cementing.

3.5. Preventive conservation

To ensure the preservation of the panel it is necessary to keep in mind preventive and passive conservation after the treatment. If the panel will be stored laying down in a drawer it must be ensured that the panel is kept without having anything on top of it, or it can be mechanically damaged. The drawer should be cool, dust free and have no chemical vapours. The optimal temperature is 20 ^{o}C, which should be as constant as possible and may fluctuate not more than 5 ^{o}C a day, as sudden or big change of temperature might create stress in the glass and as being already damaged, the damage can expand The relative humidity should be not higher than 60% and should not vary more than 5% per day. If being displayed vertically the panel should be supported in several places to provide stability of lead construction. The amount of light should not exceed 75 μW/lm. [67]

The panel should be stored on a soft base to minimise the damage that might be caused by the vibration. A plastic foam or a bubble wrap are both good for that purpose. To avoid the vibration it is suggested to store the panel in the building that is not next to the big roads.[68]

[67] K. Konsa, Artefaktide säilitamine. Tartu: Tartu Ülikooli kirjastus, 2007, p. 160.
[68] Ibid.

SUMMARY

Glass is a hard but rather fragile material. Additionally to that it can be quite easily broken, if being exposed to the unfavourable conditions stained glass deteriorates chemically. Case study of current Bachelor Thesis had at the same time broken pieces and glass deterioration.

In order to get best results it was needed to do the research before the conservation. As there was minimum information to start with, it was necessary to create an art historical background to the stained glass panel. Iconographic analysis that was carried out determined that is it most likely part of the stained glass window from 14^{th} mid-century, England.

There was done a research to have a good understanding of the problems of glass deterioration. In the beginning of research was assumed that brown stains that some glass pieces have might be caused by manganese staining, so that topic was looked into more carefully. The research showed that without SEM-analysis it is almost impossible to determine the origin of the staining. As the methods of treating manganese staining are simultaneously with their cleaning qualities rather harmful to the glass, it was decided to avoid aggressive approach.

Conservation treatment was chosen keeping in mind art historical and material-technical research. Main purpose was to preserve the panel and to harmonize its general impression. Every step of the conservation was carefully considered. It is important to know when interference with the original substance can do more harm than good. The corrosion layer was gently cleaned from the superficial dirt, but the staining was left untouched. Conservation of the panel was carried out keeping in mind guidelines of Corpus Vitrearum.

Present case was a good introduction to researching unidentified stained glass panels. By studying literature and comparing motifs it was possible to assume the date and origin. Observation of material shows that the panel is medieval and that fits iconographical analysis. As the glass had deterioration and it was necessary to research its causes. It was interesting and educative to create the treatment plan according to all gained knowledge.

14NDA SAJANDI INGLISE VITRAAŽAKNA FRAGMENT. KEEMILISTE KAHJUSTUSTE ANALÜÜS JA RESTAUREERIMINE

KOKKUVÕTE (SUMMARY IN ESTONIAN)

Keskaja hilisperiood oli Euroopas vitraaži ja klaasimaali õitseaeg. Sellest ajast on pärit kaunid aknad, mis kujutavad pühakuid ja Piibli stseene. Tagasihoidlikul kujul oli klaasimaal ja vitraaž esindatud isegi väikestes kirikutes. Hooletu suhtumine ja aeg hakkab kahjustama igat materjali ning seetõttu ollakse tänapäeval ka keskaegse klaasi kahjustuste problemaatika ees.

Antud bakalaureusetöö uurimis- ja konserveerimisobjektiks on keskaegse vitraažakna osa. Enne ikonograafilise analüüsi läbiviimist puudus kindel ajalooline taust ning seetõttu tuli läbi viia uurimus, et dateerida vitraažaken. Uurimist vajasid ka klaasi kahjustused, millest olenes edasine konserveerimine.

Bakalaureusetöö on jaotatud kolmeks osaks. Ikonograafilises analüüsi käigus tutvustatakse 14nda sajandi Inglismaa vitraažikunsti ning selle traditsioone. Teises osas on teostatud teoreetiline materjaliuuring, kus tuuakse välja keskaegse vitraaži valmistamise meetodid ning tutvustatakse klaasi keemilise kahjustuste tagamaid, põhiliselt keskendudes mangaani kahjustusele. Kolmas osa on pühendatud antud töös käsitletud paneeli uuringutele ja praktilise konserveerimisele.

Bakalaureusetöö raames on läbi viidud vitraažakna osa kunstiajalooline analüüs, mille käigus on uuritud mitmeid olulisi ajaloolisi vitraaže puudutavaid raamatuid. On välja toodud näited, mis on sarnased antud töös käsitletud vitraažakna osaga. Kõik võrdluseks toodud näited pärinevad 14ndast sajandist, enamus sajandi esimesest poolest. Analüüsi tulemusena lubab oletada, et käesolev vitraažakna fragment pärineb 14nda sajandi esimesest poolest. Antud teooriat toetab ka läbi viidud klaasi analüüs, mis viitab keskaegsetele töötlemisvõtetele.

Arhealoogilise klaasi ja mõnedel juhtudel ka *in situ* klaasi üks tüüpkahjustusi on materiali pruuniks või mustaks tõmbumine, mille tagajärjel kaotab klaas oma ühe põhiomadustest – läbipastvuse. Enamus juhtudel on mainitud nn deformatsioon tingitud mangaani kahjustusest. Mangaani kahjustus on klaasi pruuniks või mustaks tõmbumine, mille tagajärjel kaob klaasi läbipaistvus. See on tingitud Mn(IV) ioonide kontsentratsioonist klaasi kahjustunud pindmises kihi. Töös käsitletud vitraažakna fragmendi klaas on osades kohtades läbipaistmaltult pruunistunud ning seetõttu uuritakse klaasi mangaani kahjustust lähemalt.

Läbi viidud teoreetiline mangaani kahjustuse taustauuring näitas, et klaasi pruunistumist võivad esile kutsuda ka mitmed teised keemilised elemendid peale mangaani. Töö käigus läbi viidud uuringud ei andnud piisavalt informatsiooni, et kindlalt väita, kas tegemist on mangaani kahjustusega. Mangaani kahjustust on võimalik keemiliselt likvideerida, ent selleks rakendatavad meetodid on üpris agressiivsed ning võivad kahjustada klaasi veelgi enam. Seetõttu seati konserveerimisel eesmärgiks puhastada pindmine mustus ning taastada vitraažpaneeli ühtsus.

Enne konserveerimistööde algust on väga tähtis teha eelnev uurimustöö. Antud juhtum õpetas, et tuleb teada kahjustuse tüüpi, et osata seda õigesti käsitseda. Vale lähenemisviis konserveerimisele võib teha ajaloolisele objektile rohkem kahju kui kasu. Iga konserveerimine on vägivaldne sekkumine objekti ning seda tuleb alati teha teadlikult ning põhjendatult.

BIBLIOGRAPHY

Amillard-Nouger, **A**. Rameau-Monpouillan,C. Le Vitrail. Image et Atmosphere. Geneve: Aubanel, 2005.

Arnold, H. Stained Glass of the Middle Ages in England and France. London: A. & C. Black, 1913.

Baker, J. English Stained Glass. London: Thames and Hudson, 1960.

Burman, P. ed. Treasures on the Earth. London: Donhead Publishing Ltd, 1994.

Cagno, S., Nuyts, G., Bugani, S., De Vis, K., Schalm, O., Caen, J., Helfen, L., Cotte, M., Reischig, P., Janssens, K. Evaluation of manganese-bodies removal in historical stained glass windows *via* SR-μ-XANES/XRF and SR-μ-CT. – Journal of Analytical Atomic Spectrometry 2011, 26, p. 2442–2451. DOI: 10.1039/C1JA10204D.

Davison, S. Conservation and Restoration of Glass. London: Butterworth-Heinemann, 2003.

Dranke, M. History on English Glass-Painting. London: T. W. Laurie, 1912.

Duthie, A. L. Decorative Glass Processes. New York: Dover Publication, 1982.

Enghag, P. Encyclopedia of the Elements. Weinheim: Wiley-VCH, 2004.

Hergin-Barnes, P. Medieval Stained Glass of the Country of the Lincolnshire. Oxford: Oxford University Press, 1996.

Konsa, K. Artefaktide säilitamine. Tartu: Tartu Ülikooli kirjastus, 2007.

Leap, K. Silver Stain. San Francisco: Blurb, 2010.

Orial, G., Warscheid, T., Bousta, F., Loisel, C. Incidence bactérienne dans les phénomènes de brunissement des vitraux anciens, – L'Actualité Chimique 2007, 312– 313, p. 34– 39.

Schalm, O., Proost, K., De Vis, K., Cagno, S., Janssens, K., Mees, F., Jacobs P., and Caen, J. Manganese staining of archaeological glass: the characterization of Mn-rich inclusions in leached layers and a hypothesis of its formation. – Archaeometry 2011, 53, p. 103–122. doi: 10.1111/j.1475-4754.2010.00534.x.

Theophilus. Encylopedia of Christian Art of the Eleventh Century. Hendrie, R. tran. London: John Murray, 1847, p. 139.

Watkinson, D., Weber, L. and Anheuser, K. Staining of archaeological glass from manganese-rich environments. – Archaeometry 2005, 47, p. 69–82. doi: 10.1111/j.1475-4754.2005.00188.x

Weber, L., Eggert, G., Watkinson, D. A Closer Look at Brown Staining on Archaeological Glass. Preprints Nova Gorica 2007, ICOM. p. 35–45.

Williamson, P. Medieval and Renaissance Stained Glass in the Victoria and Albert Museum. London: V&A Publications, 2002.

Wood, D. Stained Glass. London: Mitchell Beazley Publishers Limited, 1976.

Other sources

Weber, L. Examination and removal of staining from Archaeological Glass.- Diploma Thesis Submitted for the Degree of Konsevierung und Restaurierung von Archäologischen, Ethnologischen und Kunsthandwerklichten Objekten.- Staatliche Akademie der Bildenden Künste, Stuttgart, 2005.

Gordon Plumb's photostream
http://www.flickr.com/photos/22274117@N08/5220987493/

Southwell & Nottingham Church History Project
http://www.nottsopenchurches.org.uk/

Vitrearum (Allan Barton)'s photostream
http://www.flickr.com/photos/vitrearum/4118061172/in/photostream

Official website of Victoria and Albert Museum
http://www.vam.ac.uk/content/articles/e/english-stained-glass-1325-1520

Official website of Corpus Vitrearum
http://www.cvma.ac.uk/conserv/guidelines.html

University of California Riverside. Central Facility for Advanced Microscopy and Microanalysis
http://micron.ucr.edu/public/manuals/EDS-intro.pdf

University of California Riverside. Central Facility for Advanced Microscopy and Microanalysis.
http://micron.ucr.edu/public/manuals/Sem-intro.pdf

LIST OF ILLUSTRATIONS

ANNEXES

Photo documentation. Before and after

Graphical documentation

Journal of practice

CD with Bachelor Thesis

PHOTO DOCUMENTATION. BEFORE AND AFTER

Figure 1. Panel in transmitted light. Front.

Figure 2. Panel in transmitted light. Back.

Figure 3. Panel in reflecting light. Front.

Figure 4. Panel in reflecting light. Back.

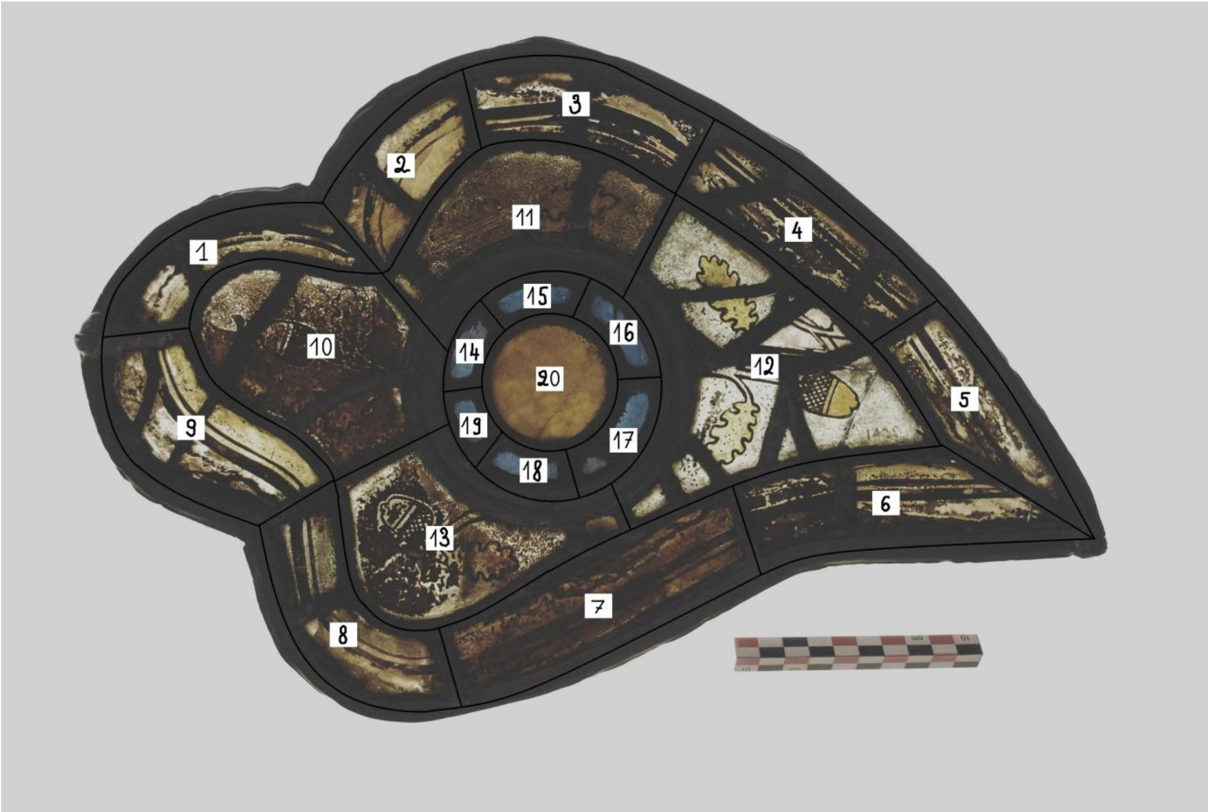


Figure 5. Division and numbering of the panel.

GRAPHICAL DOCUMENTATION

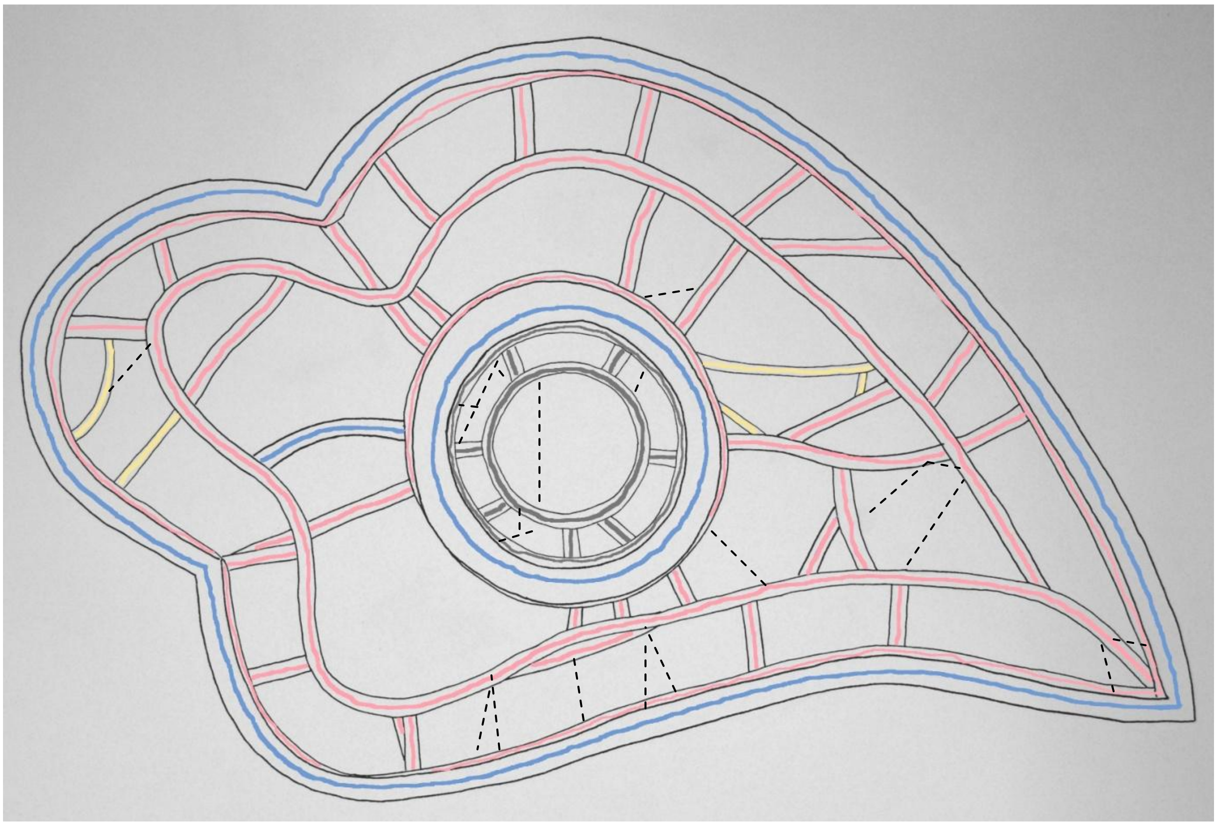
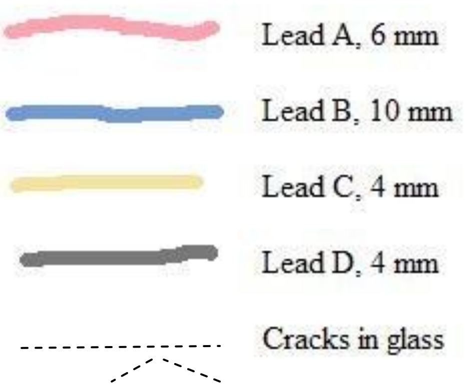


Figure 6. Documentation of different lead and cracks in the glass.



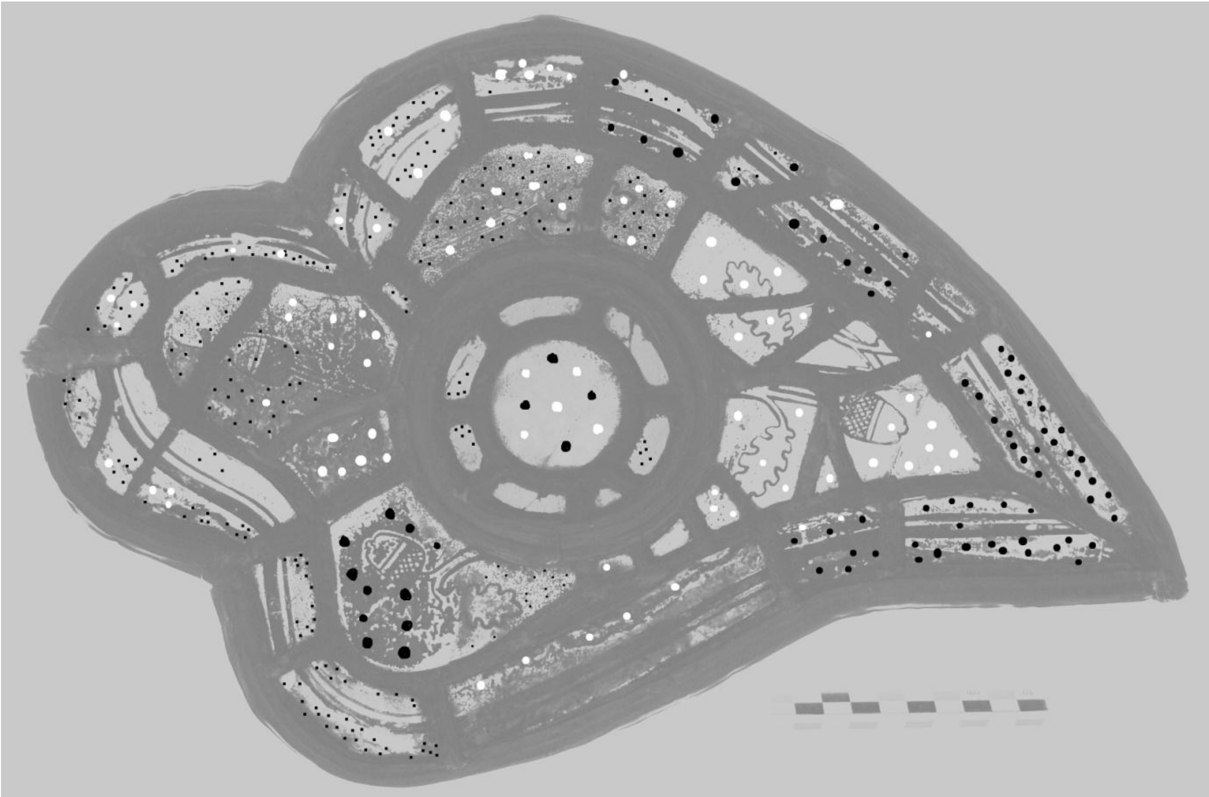
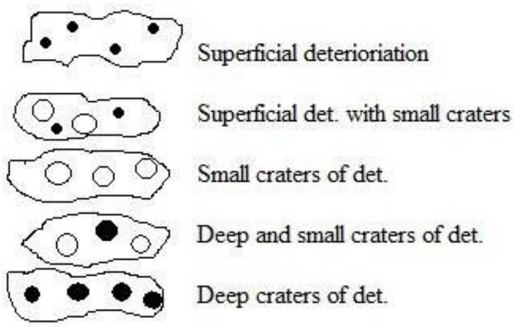


Figure 7. Documentation of deterioration. Front.



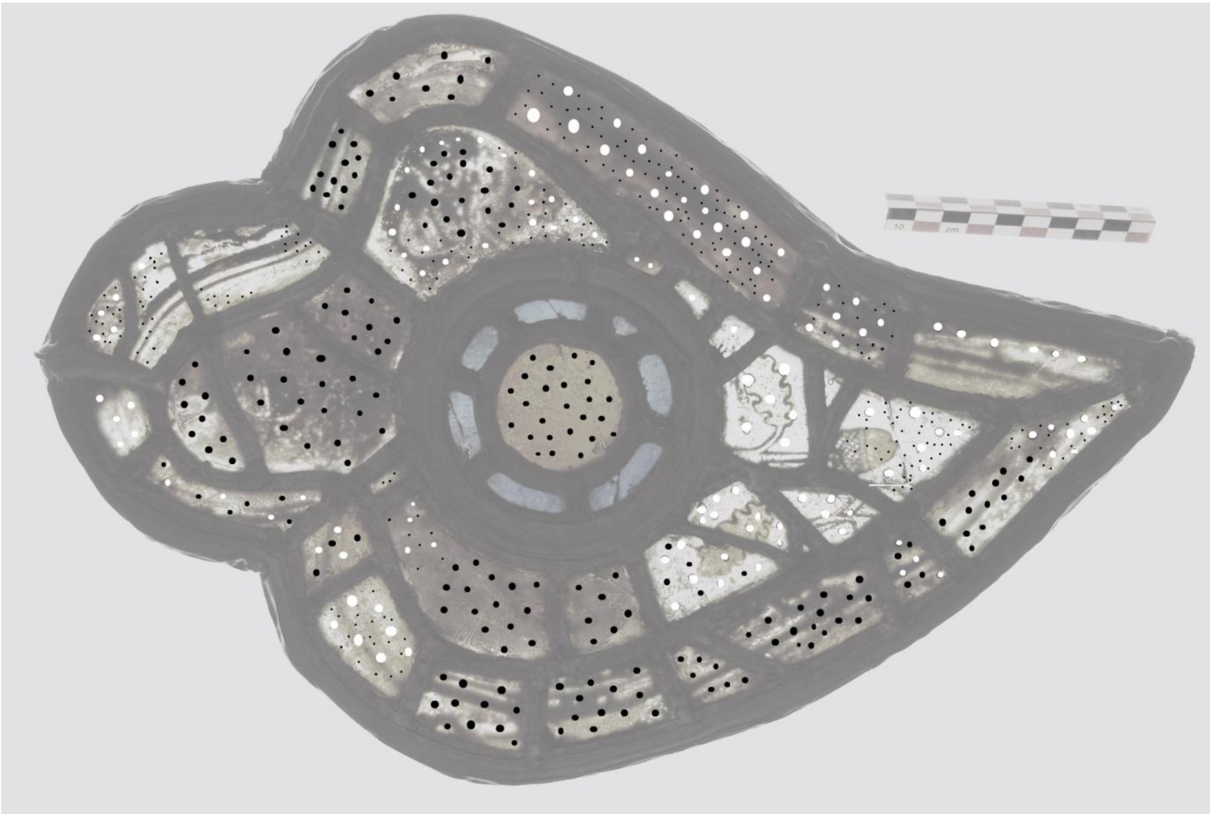


Figure 8. Documentation of deterioration. Back.

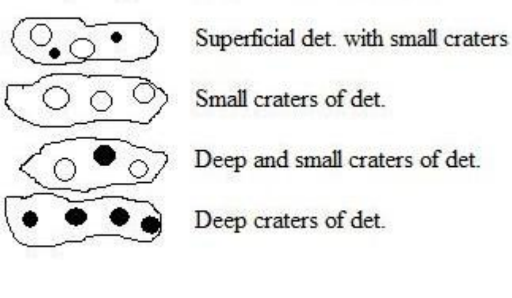


Figure 9. Documentation of possible Mn-staining location.

Figure 10. Division of the lead after the treatment.

JOURNAL OF PRACTICE

Date	Time spent	Action description	Used materials and tools.
18.10.2011	1h	Examination of the panel	
25.10.2011	2h	Photographical documentation	Camera, measuring stick
1.11.2011	4h	Graphical documentation	Unipin 0,05 , 0,3 , 0,8 mm paper, Paint, Microsoft Office Picture Manager
15.11.2011	1h	Microscopic research	Light microscope, max magnification 2,5x
22.11.2011	5h	Dismantling, taking the samples	Pincers
29.11, 01.12.2011	4h	Microscopic studies of the cross-section	Light microscope, max magnification 500x
10.12.2011	2h	Preparation of the presentation	Power Point 2007, Microsoft Office Movie Maker
14.02.2012	1h	Cleaning tests	Ethanol, water/ethanol, DMF
16.02.2012	6h	Cleaning the pieces with DMF and water/ethanol	Water/ethanol, DMF, scalpel
21.02.2012	2h	Planning the shape of the piece no. 12. First bonding.	Paper, pencil, scotch tape, scalpel, acetone, dental wax, Araldite 2020
28.02.2012	1h	Painting the infill, first baking	Grisaille paints, kiln

2.03.2012	2h	Painting the infill, second baking	Grisaille paints, kiln
7.03.2012	2h	Bonding the infill	Scotch tape, scalpel, acetone, Araldite 2020
13.03.2012	3h	Retouching piece no. 12	Inorganic pigments, Paraloid B72
20.03.2012	3h	Bonding rest of the pieces	Scotch tape, scalpel, acetone, Araldite 2020
23.03.2012	6h	Retouching the pieces	Inorganic pigments, Paraloid B72
17.04.2012	6h	Releading the panel	5 mm, 8 mm and 10 mm lead, lead knife, hammer, nails, soldering iron, oliena, tin
18.04.2012	1h	Cementing the panel	Chalk powder, linen seed oil, black pigment
24.04.2012	0,5h	Finale documentation	Camera