

Stained glass from the research of the Dubrovnik cathedral

Slikano steklo odkrito med raziskavami dubrovniške katedrale

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Abstract

The Dubrovnik Republic maintained its own glass production in the late Middle Ages, including records of window glass manufacturing. This paper will contribute to the study of stained glass in the Balkan region. It will outline late medieval stained-glass fragments (mid-14th to the first half of the 15th century) excavated from the Dubrovnik cathedral during the renewal of the building after a large earthquake in 1979 and are extremely rare in the Balkan region. Analogous examples of Dubrovnik archaeological material can be found among Western European stained-glass windows. These finds indicate that Dubrovnik was influenced by Western European technology through trade or that this way of making stained glass began to be applied in local workshops.

Key words: Dubrovnik, cathedral, late Middle Ages, stained glass, local production

Izvleček

Dubrovniška republika je imela v času poznega srednjega veka lastno proizvodnjo stekla, ki je vključevala tudi proizvodnjo okenskega stekla. Članek prinaša novosti v študiju vitražev na Balkanu. Predstavlja odlomke obarvanega okenskega stekla z vitražev (sredina 14. – prva pol. 15. stoletja), ki so bili odkriti med obnovo dubrovniške katedrale po potresu leta 1979 in predstavljajo redkost med steklenimi najdbami na Balkanu. Primerjave predstavljenemu gradivu najdemo med najdbami v zahodni Evropi. To kaže na vpliv tehnologije zahodno evropskih delavnic, ki je dosegla Dubrovnik s trgovino ali pa so lokalne delavnice v svoji proizvodnji kopirale zahodno tehnologijo.

Ključne besede: Dubrovnik, katedrala, pozni srednji vek, vitraži, lokalna proizvodnja

Introduction

The Dubrovnik Republic had a significant influence on trade in the late Middle Ages and early post-medieval times. Its position made it an intermediary for the trade of various goods between the East and West. In addition to various merchandise, they also traded in glassware – buying various items from the Eastern Mediterranean to Western Europe and selling domestic glass products in the Balkan hinterland and throughout the Mediterranean,

as the City had its own glass production from the 14th to the 16th centuries (Han 1981). This indicates that Dubrovnik had developed crafts, as well as a high culture of living and extensive trade connections.

Earthquakes are frequently recorded in the Dubrovnik area, and this fate befell the cathedral as well. These circumstances damaged the cathedral several times, but it was always restored. Unfortunately, this beautifully decorated Romanesque building did not survive the Great Earthquake that struck the city in 1667. After

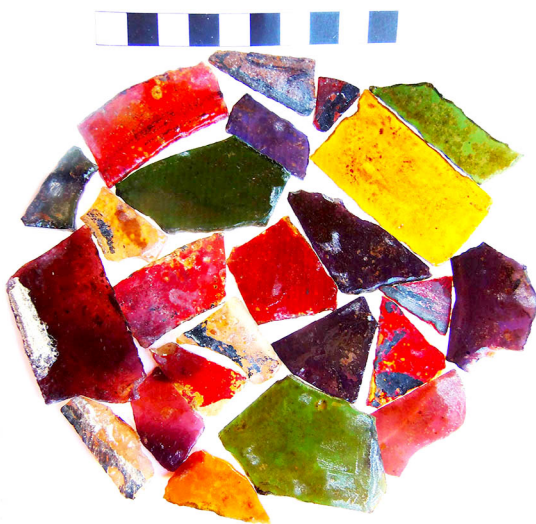


Figure 1: Archaeological finds of stained glass from the Dubrovnik cathedral, 14th-15th century (all photos by the author).

that catastrophe, a new Baroque cathedral was erected, which still stands proudly in Dubrovnik today. The last major earthquake that struck the city also dealt damage to the cathedral in 1979 (Horvat-Levaj 2016, 25). This last strong earthquake was followed by the restoration of many historic buildings in the city, including the cathedral, and archaeological excavations were also carried out during this time. The cathedral was explored between 1981 and 1987, and in addition to many fragments of stained glass (Fig 1),¹ a number of finds of various types, origins and date were also found (Stošić 1988, 15–36; Stošić 1989, 326–338).

Fragments of stained glass from the Dubrovnik cathedral are very rare archaeological finds of this kind in the Balkans. So far, only a few archaeological excavations in the Balkan region have resulted in similar finds: Kraljeva Sutjeska in Bosnia (Anđelić 2004, 228–229; Han 1981, 75), Studenica in Serbia (Stamenković

2015, 369–372, Fig. 6), Brškovo in Montenegro (Živanović 2018, 51–53, Fig. 3), and the island of Mljet in Croatia (Topić *et al.* 2016, 575, 578, 587, Fig. 1/20; Topić 2017b, 52–53).

Stained glass origins and techniques

Windowpanes have a long tradition, and their manufacture is believed to have been found in Egypt (Gasparetto 1958, 149). The Romans made windowpanes in the 1st century (Brisac 1986, 7; Gasparetto 1958, 149; Ignatiadou and Antonaras 2011, 57; Kanyak 2009, 26), and glazed windows were already common in not only late antique sacral buildings but also in private houses (Milavec 2015, 79–80, 93). In the Middle East, windowpanes were also used in Muslim buildings (Brisac 1986, 7). In Early Byzantine window architecture, small windowpanes have been documented, made in various techniques (Kanyak 2009, 26, 35, 40). Such windows were used in Western Europe during the Middle Ages. These first stained glass windows probably had a purely decorative function (Brisac 1986, 7).

In the 7th century, glass was intentionally coloured, and the forerunners of stained glass were developed (Milavec 2015, 81). Stained glass details are made by the process of glass staining, which has been in use since the Early Christian period (Ignatiadou and Antonaras 2011, 26). It is probable that stained glass windows were first painted in Western Europe. Religious depictions intended for the education of believers were painted. In the beginning, these were small stained-glass panels because they had to be adapted to the architecture of the time (Brisac 1986, 7). The windows of Romanesque buildings already show the high quality of painting, as well as precision of execution and the elaborate nature of these structures (Brisac 1986, 10–14), which is still much improved in Gothic-Renaissance stained glass (Brisac 1986, 33–130; Chieffo Raguin 2013, 33–35). Lead came replaced plaster, stucco and wooden armature, which simplified the making of windows because even smaller pieces of glass could be easily inserted (Brisac 1986, 7).

¹ The material presented here is part of the project Discovering of old Dubrovnik cathedrals – Research-educational workshops of the Department of Art History, Faculty of Humanities and Social Sciences, University of Zagreb and City parish of the Assumption of the Virgin Mary in Dubrovnik. These stained-glass finds will be published as part of a book expected in late 2022.



Figure 2: Stained glass windows, Canterbury cathedral, 13th century.

Monumental churches and cathedrals were built in Europe around 1200, and the size of their windows was particularly pronounced in Gothic cathedrals with finely painted stained glass (Brisac 1986, 33–34; Cowen 2008, 9, 11; Gasparetto 1958, 151–153). Sacral buildings now use large windowpanes to present biblical stories through images, which are understandable to the poorly educated and often illiterate believers (Fig. 2). Scenes from everyday life in the late Middle Ages were also created (Brisac 1986, 14; Chieffo Raguin 2013, 29–48; Cowen 2008, 18, 21).

If we exclude the cost of construction, stained glass was the most expensive segment of the building and was an important part of window architecture. The masters who painted them were highly respected artists (Raguin 1986, 30). The process of making stained glass re-

quired good cooperation between artists and patrons, who financed the costs of their production (Chieffo Raguin 2013, 42, 55). However, in addition to sacral structures, secular buildings also had glazed windows, which is especially noticeable in the 14th century in developed areas. In western Europe, window glazing was considered a luxury, so there were special taxes on private window glass (Sarti 2006, 109).

Several techniques were used to make windowpanes: casting, crown and cylinder. The casting technique was applied in the Roman period to obtain flat window glass by pouring glass mass on a flat surface or into an open shallow mold (Ignatiadou and Antonaras 2011, 57; Kan-yak 2009, 26–27, Fig. 1; Milavec 2015, 80). However, such glass was often uneven and did not provide the necessary transparency but affect-

ed the more beautiful experience of the interior of the building (Milavec 2015, 80). The crown glass technique was performed in a way to blow a paraison, which would open and rotate rapidly until a glass disc was created under centrifugal force. It was primarily used to make circular glass (discs) but could also be cut into rectangular pieces (Brisac 1986, 180–181; Chieffo Raguin 2013, 15; Ignatiadou and Antonaras 2011, 55; Kanyak 2009, 33–34, Fig. 14). This technique was applied throughout the Roman Empire in the 4th century (Kanyak 2009, 33). The Romans also utilized the technique of cylinder blown sheet – a blown glass cylinder is cut along its long side, and such flat sheets of glass are cut into smaller rectangular pieces (Ignatiadou and Antonaras 2011, 104; Kanyak 2009, 38–39, Fig. 25). The cylinder technique is characterized by the procedures used in free blowing (capturing the glass mass with a blow pipe and blowing the paraison), but it is also necessary to level the glass on a flat metal surface until the shape of the cylinder is obtained. This was followed by punching and expanding the top of the cylinder, removing it from the blow pipe, cutting it longitudinally, and reheating and separating the two glass flat sheets (Brisac 1986, 180; Chieffo Raguin 2013, 15; Kanyak 2009, 38–39, Fig. 25). The technique was used from the beginning of the 2nd century to the beginning of the 19th century (Kanyak 2009, 38). This is the most common and the most effective technique used in making stained glass.

The design of stained-glass depictions was made on a scale of 1:10. The colours of the glass available at the workshop were also selected (Brisac 1986, 181). Next, depictions of exact dimensions were made on wooden boards and on paper (Brisac 1986, 181–182; Chieffo Raguin 2013, 25–26). This was followed by cutting pieces of glass. Glass cutting was a separate craft from glassmaking. Masters who specialized in cutting glass knew how to straighten glass mass and cut it into various shapes, as well as join pieces of glass to lead comes (Roller 1951, 137). In the Middle Ages, glass was cut with red-hot iron, requir-

ing great skill of a master. However, as early as the end of the Middle Ages, diamond was used to cut glass, which contributed to the result (Brisac 1986, 182). After cutting, stained glass was painted, and fired in an oven to solidify the paint (Chieffo Raguin 2013, 26–27).

Stained glass can be composed of quadrangular, circular, or other pieces of glass, which are inserted into a panel using lead comes or plaster (Ignatiadou and Antonaras 2011, 26). There were also masters who framed glass panels into window frames, but they were also engaged in the production of glass (Roller 1951, 138). The windows were divided into parts of less than one square meter during construction, and were later joined (Brisac 1986, 16, 185).

A detailed description of the making of stained glass can be found in Theophilus (*Treatise on Diverse Arts / De diversis artibus* – The second book, *The Art of the Worker in Glass*; 12th century), who wrote about the process of glass cutting, painting, casting comes and assembling glass (Theophilus, book 2, chapters 17–29, pages 61–72; Brisac 1986, 186–187; Chieffo Raguin 2013, 16–179).

Archival data on window glass and glassmakers in Dubrovnik

Dubrovnik churches were already ornamented with stained glass in the 14th century, which can be seen in archival sources (Han 1971, 52). The Franciscan church of the Little Brothers (*Mala braća*) in Dubrovnik had glazed windows as early as 1348. It is possible that they were made as a combination of polychrome polygonal glass pieces and oculi that were embedded in lead comes, or of monochromatic and polychromatic oculi. Apse windows of the church of St. Dominic were glazed around 1366 (Han 1979, 457–459).

Benedictine monasteries were the primary centres of glass production in the Middle Ages. Although the number of glass workshops affiliated with monasteries declined considerably in the following centuries, the making of stained glass still took place in such workshops during the 14th and 15th centuries, especially among the

Franciscans, Dominicans and Jesuits (Han 1981, 47–48, note 17).

In the first decades of the 15th century in the western (Pile) and eastern (Ploče) parts of the city, multiple craft workshops could be found, including those that produced glass. In 1418, the Dubrovnik Small Council decided to build a small glass workshop in the Dominican monastery, which would house a glassmaker, a Dominican friar, specialized in stained glass (Han 1981, 46–47). The archival documents list the names of Dubrovnik masters of glassmaking, among which the first known master of stained glass documented was the Dominican monk Petar (*frater Petrus a fenestris, magister vitri, magister vitriorum fenestrarum*) (Han 1981, 48–49, 55). Glassmaker Petar Božiković-Natalis from Zadar (*Petrus, Piero Boxicchouich-Natalis*), who was not a monk, also made windowpanes in Dubrovnik (Han 1981, 49, 65–69). Nikola Petrov (*Nicola Petri*), the son of the glassmaker friar Petar, specialized in making stained glass as well (Han 1981, 55, 69–70). He had the title of *magister vitriorum fenestrarum* and was accepted into municipal service in 1444 (Han 1981, 57). Dubrovnik was a very developed city in both economic and cultural terms, so it is expected that it had masters specialized in making stained glass. Even in smaller parts of Europe, masters of making and painting stained glass were very common artisans-artists (Marks 1993, 41). The price of one glazed window in Dubrovnik was 7.5 gold ducats (according to 8 red windows that cost 180 perpers = 60 gold ducats) (Han 1981, 73).

Throughout the 15th century, the glazing of windows in Dubrovnik churches continued. The Church of St. Blaise (St. Vlaho) received windows in 1440 (Han 1971, 55; Han 1979, 463; Han 1981, 52), and the monastery of St. Claire (St. Klara) was glazed in 1433 (Han 1971, 54; Han 1979, 462–463; Han 1981, 51). In addition to sacral structures, secular, and private buildings (houses of nobles and merchants) in Dubrovnik also had glazed windows (Han 1971, 55–56; Han 1979, 463; Han 1981, 67). The Rector's Palace was glazed with stained glass in 1434, but the win-

dows were damaged in 1435 in an explosion and fire, and were rebuilt in 1442 (Han 1971, 55; Han 1979, 463–464; Han 1981, 67–69). It seems that these stained-glass windows did not last long, because as early as 1463, there was an explosion of gunpowder in the Palace, which caused great damage to the building and probably the stained-glass windows with it (Han 1979, 464; Han 1981, 68).

Archival documents state that masters who painted stained glass also worked in local workshops. The stained-glass master and painter Bernard Nikolin (*Bernardus Nicole vitrarii, pictor, magister fenestrarum de vitro*), who collaborated with the local painter Vukac Rajanović (*Vuchaz Raianouich*), is mentioned. The Dubrovnik school of painting flourished in the third decade of the 15th century, at a time when intensive stained-glass production was taking place, so painting and glassmaking likely functioned in a complementary manner (Han 1981, 72, 76).

One archival data is particularly interesting regarding the stained glass from the Dubrovnik cathedral: Friar Petar, a Dominican monk in Dubrovnik, is mentioned as a glazier who in 1431 undertook the making of eight high-quality red glass windows with white frames for the cathedral. It is possible that these windows represented red flashed glass. They were made for the dome of the cathedral (Han 1979, 461–462; Han 1981, 50–51, 73), while other polychromatic stained-glass windows from the cathedral were not mentioned in archival documents.

According to archival data, some windows of the Dubrovnik cathedral were broken in 1573 and replaced. Their complete destruction occurred in 1667, when the cathedral collapsed in the greatest earthquake that struck the city (Han 1979, 462; Han 1981, 51).

Finds

It is possible that stained glass windows were imported to Dubrovnik from Venice in the 14th century, or that Murano masters came to Dubrovnik to make them (Han 1971, 54; Han 1979, 460). The Venetians made stained glass

for many Italian cities, and less for Venice itself (Gasparetto 1958, 154–155; Han 1971, 54). However, in the 15th century, domestic glassmakers made windowpanes for Dubrovnik buildings in local workshops (Han 1979, 465), and archival data testify that, at that time, Dubrovnik craftsmen specialized in glassmaking went to Venice to get tools (Han 1981, 57).

Dubrovnik developed intensively during the 14th and in the first half of the 15th century, so the number of stone buildings (sacral and secular) increased, which caused a greater demand for glazed windows (Han 1971, 52; Han 1981, 48). It can be assumed that the cathedral, as the most important sacral building, had more luxurious stained-glass windows than other buildings in Dubrovnik. Although glass finds from the research of the Dubrovnik cathedral are numerous and of different shapes, they are very fragmented and with modestly preserved paintings.

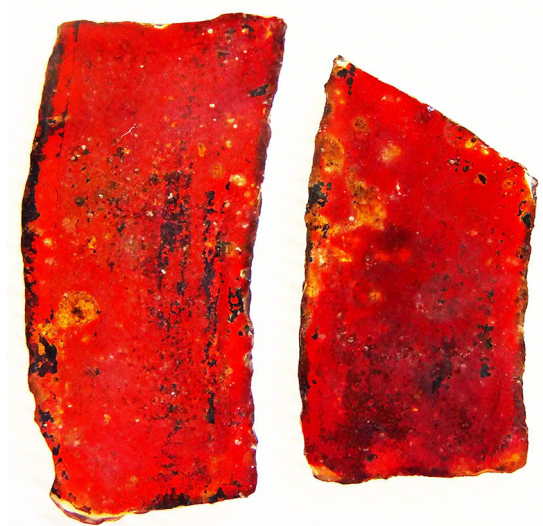


Figure 3 Pieces of red *flashed* stained glass (H. 51 cm; H. 4.4 cm), Dubrovnik cathedral, 15th century.

The finds are of diverse colours: yellow, ochre yellow, red, purple, green, brown violet (Fig. 1, 3–14), cobalt blue, and turquoise (Fig. 15). Among the material, red flashed glass (made of a lower thicker and colourless or yellowish layer of glass, and an upper thinner red layer of much



Figure 4: Fragments of yellow stained glass with black painting (H. 1.8 cm; H. 2.5 cm), Dubrovnik cathedral, 14th– 15th century.



Figure 5 Fragments of yellow stained glass with black painting (H. 4.9 cm; H. 3.7 cm; H. 3.3 cm), Dubrovnik cathedral, 14th– 15th century.



Figure 6: A rectangular piece of yellow stained glass (H. 32 cm, W. 6.2 cm), Dubrovnik cathedral, 14th– 15th century.

higher density) stands out (Fig. 3, 11–12). Black painting is preserved on several fragments (made of red flashed, yellow, ochre yellow and brown

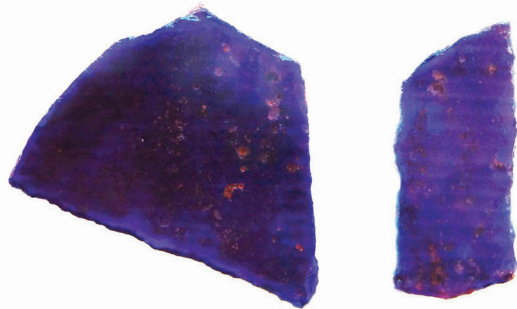


Figure 7: Fragments of purple stained glass, Dubrovnik cathedral (H. 37 cm; H. 34 cm), 14th–15th century.



Figure 8: A rectangular piece of brown violet stained glass (H. 2.8 cm, W. 6.4 cm), Dubrovnik cathedral, 14th–15th century.

violet glass – Figs. 4–5, 9, 11), but insufficiently to reconstruct its depictions. Lead comes (Fig. 16) in which the cut glass pieces were inlaid, and copper wire mesh remains (for protection of windows) were found as well (Fig. 17). Thick mortar lines can be found in some fragments, which revealed the way in which the panels were attached to the stone frames (Fig. 14). These finds demonstrate the methods of installation and protection of stained glass in late medieval Dubrovnik, which were the same as in the largest centres of that time.

Although the paintings are poorly preserved, based on Philip de Diversis's allegation that there were depictions of saints on stained glass in the cathedral (De Diversis, part II, chapter 4, page 27; Han 1979, 462), we can assume some simplified iconographic solutions. Some fragments of yellow glass have painted black curved lines that may represent parts of saintly halos (Fig. 4) as part

of a larger stained-glass composition. Theophilus states that such motifs were painted on yellow glass (Theophilus, book 2, chapter 21, page 65), which was common on the stained-glass windows of many European cathedrals and churches throughout the 12th and 13th centuries (Brisac 1986, 80–81, 91–92, 103; Williamson 2003, 17, 36, 131, 135, Figs. 1, 19). Yellow glass (Fig. 5) was also used to depict hair, hands, feet, wings, and gold. Saintly halos could also be made of red glass (as in the cathedrals of Canterbury, Troyes, Chartres, Auxerre, Saint-Denis, Reims) (Brisac 1986, 12, 37, 57, 91; Chieffo Raguin 2013, 102, Fig. 70; Williamson 2003, 20, 25, 27–29, 32–33, 37, 40, 46, 132–136, 138, Figs. 4, 9, 11–12, 15–16, 20, 23, 29). Among the finds are two slightly curved pieces made of red flashed glass (Fig. 3), which could have served such a purpose, but could also have formed part of the frame of some iconographic display (like those in French cathedrals through the 12th–14th centuries) (Brisac 1986, 12, 57, 66, 88; Chieffo Raguin 2013, 34, Fig. 20; Williamson 2003, 25, 27, 30–36, 44, 133–135, 137, Figs. 9, 11, 13–19, 27). One piece of stained glass is rectangular in shape and made of ochre yellow glass, and probably served as the frame of some depiction (Fig. 6). A smaller number of purple (Fig. 7) and brown violet (Figs. 8, 9) fragments of glass were found, while green glasses are quite numerous (Fig. 10). These colours of glass were used for various parts of the composition (frame, clothing, decoration, field filling), as evidenced by depictions from Western European cathedrals and churches (Brisac 1986, 12, 14–15, 42, 52–55, 70–71, 96–97; Chieffo Raguin 2013, 30–31, 34, Figs. 18, 20; Williamson 2003, 25, 28, 30–32, 35, 39–40, 43, 136–137, Figs. 9, 12–14, 16, 18, 22–23, 26).

Red flashed glass from the Dubrovnik cathedral (Fig. 3, 11–12) is made of yellow glass dipped in a pot with red glass using the *cylinder blown sheet technique*. The layered glass cylinder was then opened and, while it was hot, was cut lengthwise thus obtaining flat sheets of coloured glass.

When a thick red glass mixture was applied in thin layers to the base glass, a ruby red

effect was achieved. Otherwise, a very expensive ingredient – gold – was used to make ruby red glass, which made it necessary to invent a cheaper method of production. This prompted the development of the flashing technique, by applying a layer of thick red paint obtained with copper oxide to the base of the window glass (Kunicki-Goldfinger *et al.* 2014, 103). Red glass is poorly permeable to light, so it had to be applied in very thin layers on as colourless a base glass substrate as possible (Williamson 2003, 9), so that daylight could effectively reach the interior of the space.

Red flashed glass forms part of the stained-glass compositions of Western European cathedrals, dating from the 12th to the 16th century (England - York Minster, France, the Netherlands, Germany, Spain). Analysis of this glass showed that a thin layer of glass above the yellow glass was obtained by use of copper oxide, which is represented by 1% in all cases (the red layers have a high-Cu, and the colourless / yellow have low-Cu) (Kunicki-Goldfinger *et al.* 2014, 89–95, 101). Analysis also showed that it was potassium (forest) glass obtained using wood ash, which is characteristic of Western Europe. Additionally, medieval red flashed glasses are not a homogeneous group in terms of chemical composition. The layers of colourless and coloured glass differ in composition, indicating that the red glass was not obtained in a simple way – by adding copper to a mass of colourless glass – but that the masses were prepared separately (Kunicki-Goldfinger *et al.* 2014, 98–101). The existence of two basic types (with subtypes) of red glass has been documented: A – a multilayer glass of striated structure with several white and red layers (made before 1400); B – two or three separate layers with only one red (from late 14th century): B-2 – a simple red layer overlying a white base & B-3 – with an additional white layer over the red – the coperta layer (Kunicki-Goldfinger *et al.* 2014, 93–94, 102–103). The finds from the Dubrovnik cathedral correspond to type B-2.

Analyses of medieval red flashed glass from Western Europe revealed that it was stained



Figure 9: Fragments of brown violet stained glass with black painting, Dubrovnik cathedral (H. 18 cm; H. 2 cm; H. 2.1 cm), 14th- 15th century.

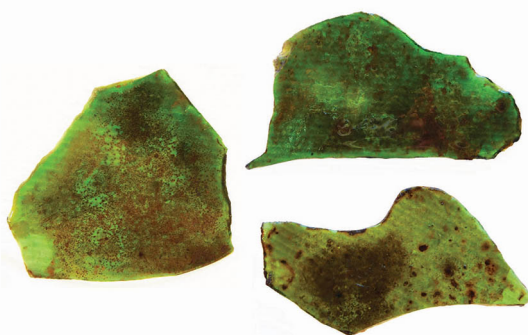


Figure 10: Fragments of green stained glass (H. 6 cm; H. 4.4 cm; H. 35 cm), Dubrovnik cathedral, 14th- 15th century.

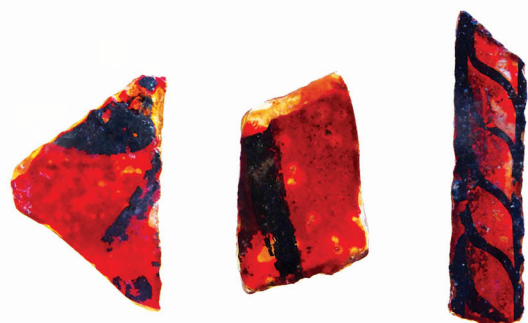


Figure 11: Pieces of red flashed stained glass with black painting (H. 38 cm; H. 2.2 cm; H. 4.5 cm), Dubrovnik cathedral, 15th century.

with copper nanoparticles, and that gold (commonly used to obtain a red colour) was not found in the composition. The technology of making flashed glass type A (striated structure), has not been demonstrated from the early 15th



Figure 12: Fragments of red flashed stained glass (W. 3 cm; W. 2.8 cm), Dubrovnik cathedral, 15th century.

to the 20th century, and perhaps until recently, so the archaeometric analysis carried out by J. Kunicki-Goldfinger *et al.* (2014, 103–104) represent a rediscovery of this forgotten medieval technique. Fragments of stained glass made of two or more layers of red glass were found in the excavations of the Paderborn cathedral as well, and date from the second half of the 12th century (Lobbedey, Wedepohl, and Kronz 2008, 124). But, flashing technique could have been even more sophisticated as we see in the example of potassium glass from Carthusian monastery at Pavia in the 15th century, which was made of layers of blue and purple, green and colourless, and red and colourless glass (Azzoni *et al.* 2005, 381–388).

According to archival sources, Venetian glaziers at the time did not make red transparent window glass, so such an origin can be discarded according to current knowledge. In Venice, in the church of San Giovanni e Paolo from the end of the 15th century, fragments of red stained glass were found. Analysis of this glass demonstrated that it is potash glass, i.e. imported from northern Europe (Verità 2013, 532).

It is believed that this complex and mysterious technique of making red glass was limited to a small number of workshops and skilled craftsmen (Kunicki-Goldfinger *et al.* 2014, 101, 104). The red flashed glass from the Dubrovnik cathedral can be associated with the year 1431, when the glassmaker friar Petar committed to make eight quality windows from red and white glass for the dome of the cathedral (Han 1979, 462; Han 1981, 50–51). This possible production of red flashed glass in a Dubrovnik workshop reveals excellent contacts between domestic glass-



Figure 13: Pieces of stained glass with serrated edges (H. 4.7 cm; H. 3.5 cm; H. 4.5 cm), Dubrovnik cathedral, 14th–15th century.

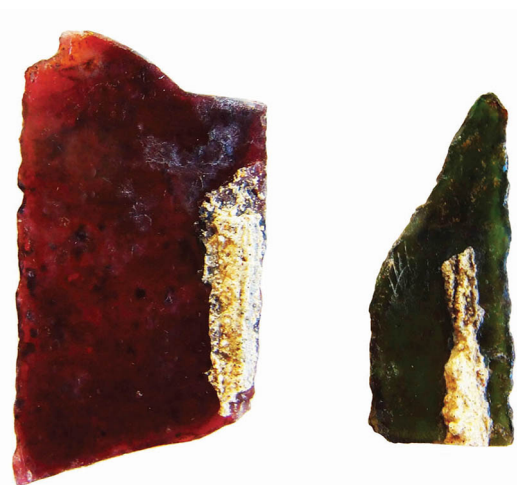


Figure 14: Fragments of corroded stained glass with lines of mortar (H. 5.8 cm; H. 4.3 cm), Dubrovnik cathedral, 14th–15th century.

makers and Western European craftsmen and technologies. It also indicates that Dubrovnik followed the highest technological trends of glassmaking and the use of stained glass in the late Middle Ages. Fragments of red flashed glass from the Dubrovnik cathedral need to be chemically analysed in order to know their origin more reliably.

Stained glass finds from the Dubrovnik cathedral can be dated from the middle of the 14th century (because they already existed in the local churches of the begging orders – Franciscan and Dominican – so it is to be expected that

the most important sacral building in the city also had them (Han 1979, 459–460) until 1440 (when Philip de Diversis mentions the stained glass windows of the cathedral in his book *Description of the Famous City of Dubrovnik*, in which he states that the windows were painted with depictions of saints) (De Diversis, part II, chapter 4, page 27; Han 1979, 462; Han 1981, 51). V. Han (1979, 462) expressed the opinion that the red glass, which was made for the dome of the cathedral in 1431, was probably the final part of the stained glass, and that the other stained-glass windows were installed earlier. Precise dating of the finds via stratigraphy is not possible because they were found in backfilled layers of rubble without accompanying material to date them exactly, but we can rely on the mentioned archival-historical data and analogous examples. Only rare fragments of oculi (15th–16th century) and early post-medieval glazed pottery were found with the remains of stained glass, which does not coincide with the dating of stained glass. Cobalt blue and turquoise blue fragments (Fig. 15) differ in the type and thickness of the glass, so it is possible that they are not from the same period as other stained glass finds. This is also indicated by the context in which they were found: the northern vaulted room behind the sacristy, with the finds of Italian and Turkish (Iznik style) glazed pottery from the 15th–16th century (Topić 2017a, 59–79).

Since the Dubrovnik fragments of stained glass are made of a wide range of vivid colours, they certainly created beautiful scenes, the effectiveness of which was contributed to by the details painted in black. After the pieces of glass were arranged in imaginary scenes, it was necessary to paint them. The colour applied to the stained-glass windows was dark brown or black and enamel-like. In Theophilus, we find data on the preparation of a painting mixture. First, the copper had to be crushed and burned until it became a powder. Then pieces of green and Byzantine blue glass had to be ground separately. All three ingredients were then mixed in a ratio of 1/3 each. They were then ground on the same



Figure 15: A fragment of blue window glass (H. 3 cm, W. 58 cm), Dubrovnik cathedral, 15th–16th century (?).



Figure 16: H-section lead comes (in which the cut glass pieces were inlaid), Dubrovnik cathedral, 14th–15th century.

stone with wine or urine and placed in an iron or lead pot. He also stated that it was necessary to use three shades of colour for highlights on glass (Theophilus, book 2, chapters 19–20, pages 63–64). Typically, multi-layered coats of paint were applied, and the details were painted at the end. When the painting process was over, the enamel had to be fixed, so the painted stained-glass windows were heated in an annealing or cooling furnace, at temperatures that had to be significantly lower (approximately 680 °C) than the melting point of the substrate (1300–1500 °C) in order to not melt (Marks 1993, 34, 36; Chieffo Raguin 2013, 14, 26–27; Cowen 2008, 12).

A large number of fragments of H-section lead comes were found in the investigation of the cathedral (Fig. 16). This lead armature was probably made by the master friar Petar because he was also engaged in casting lead plates for cov-

ering churches (Han 1981, 54), so he could apply this knowledge when assembling glass panels. This way of connecting pieces of glass as a whole was much faster and more efficient than wooden frames, because lead is soft and easy to shape, which allowed the masters to more freely create a variety of iconographic scenes. The edges of some pieces have been preserved serrated because they were cut with grozing iron, indicating that these pieces had irregularities that were corrected in this way to fit in the provided frames (Fig. 3, 8, 13) (Brisac 1986, 182; Chieffo Raguin 2013, 16, 27). After the fragments were inserted into the lead frames, they were joined as a whole by soldering to reinforce the lead lattice, and the finished glass panels were placed in the groove of the stone window frame. The frames were mostly made of flat wrought iron bars, but in the Romanesque period, wooden frames were sometimes used as well. Glass panels were fastened to the stone frames with mortar, and T-bars and clamping wedges were used for the iron window frames (Brisac 1986, 185; Chieffo Raguin 2013, 27; Rauch 2004; Marks 1993, 36–37). Finds of fragments of stained glass with thick lines of mortar (Fig. 14) from the Dubrovnik cathedral indicate that, in the 14th–15th century in Dubrovnik, the same techniques of installing stained glass were applied as in the largest Western European centres.

The stained-glass windows had to be waterproof, and in order to achieve this, cement or a glazing compound (made of whiting powder – calcium carbonate, linseed oil and drying agent) were applied with a brush. It was necessary to leave the glass for a few days for the cement to dry (Brisac 1986, 184–185; Chieffo Raguin 2013, 27).

Fragments of copper wire mesh to protect the outside of the stained glass are also important finds from the Dubrovnik cathedral (Fig. 17). Copper wire mesh and iron frames are the products of domestic workshops, as evidenced by the Dubrovnik archives (Han 1971, 54–57; Han 1981, 73, 75; Roller 1951, 137–138). Such a



Figure 17: Remains of copper wire mesh (for protection of windows), Dubrovnik cathedral, 14th–15th century.



Figure 18: Corrosion on a piece of green stained glass (H. 35 cm, W. 7.5 cm), Dubrovnik cathedral, 14th–15th century.

form of stained-glass protection is also found on modern buildings.

Stained-glass windows, in addition to decorative and educational, had the role of protecting the building from external influences, and were constantly exposed to various atmospheric changes, UV radiation from the sun, and pollution caused by humans and animals (pigeons, bats, different microorganisms – mold, algae). As a result, stained glass windows on both sides were often covered with a thick, sticky layer of dirt (dust, candle soot, glass glue and similar substances), which was sometimes mixed with

corroded layers of paint. Such material can be found on fragments of stained glass from the Dubrovnik cathedral. The deterioration of the lead lattice and frame also affected the glass and caused structural damage. Vibrations generated during the use and repair of the building also had a detrimental effect and could cause damage and increase corrosion. The glass can sometimes be completely affected by corrosion, causing their opacity. The formation of a brown layer due to the oxidation of manganese – browning, is particularly characteristic of glass from the 13th-14th century (Rauch 2004). This phenomenon is also visible on the Dubrovnik fragments, especially on purple and green glass (Fig. 18).

Final remarks

These attractive fragments of stained glass from the Dubrovnik cathedral represent very rare finds of this kind in southeast Europe. The glass is made of different colours, and some have black painting. Dubrovnik stained-glass windows were made using the *cylinder blown sheet* technique, which was more effective than the *casting* or the *crown technique*. The glass thus obtained was very suitable for stacking windowpanes and framing. Red flashed glass found demonstrates that Dubrovnik followed the latest trends of Western Europe.

Although the origin of the material from the cathedral is not entirely clear, we can assume that the stained-glass windows from the Dubrovnik cathedral may have been partially produced in Dubrovnik under Western European influence (as evidenced by native glass-maker friar Petar initiating the creation of eight windows of high-quality glass with red interior and white frames for the cathedral in 1431) or imported from western Europe (14th century stained-glass).

The cathedral stained-glass could have been made between the mid-14th century (at which time stained-glass was already in use in the city according to archival documents) and 1440 (when Philip de Diversis mentioned the cathedral glass windows with representations of saints

in his book). The cathedral windows were damaged in 1573, and the 1667 Dubrovnik earthquake caused their final destruction. The windows were of high quality since they lasted for approximately 230 (red flashed glass) or 300 years (other glass).

Future chemical analysis will offer more answers about these significant finds, and hopefully will reveal the workshop from which they originate. Dubrovnik was one the most developed cities in the Mediterranean at that time, which was due to its extensive trade and important geographical position. This enabled the arrival of the best products and craft novelties, including this beautiful polychromatic window glass.

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Summary

Stained glass windows were an important part of late medieval window architecture, and they had both a decorative and educational function. The Dubrovnik Republic maintained its own glass production in the late Middle Ages, with records of window glass manufacturing as well. Dubrovnik developed intensively during the 14th and in the first half of the 15th century. Fragments of stained glass from the research of the Dubrovnik cathedral are numerous and of different shapes, but very fragmented with modestly preserved paintings.

The finds are of diverse colours: yellow, ochre yellow, red, purple, green, brown violet, cobalt blue, and turquoise. Among the material, red flashed glass (made of a lower thicker and colourless or yellow layer of glass, and an upper thinner red layer) stands out. Black painting is preserved on several fragments, but insufficiently to reconstruct its depictions. Lead comes in which the cut glass pieces were inlaid and copper wire mesh remains (for protection of windows) were found as well. Thick mortar lines can be noticed in some fragments, which

revealed the way in which the panels were attached to the stone frames. These finds demonstrate the methods of installation and protection of stained glass in late medieval Dubrovnik, the same as in the largest centres of that time. Since archaeological finds of stained glass are extremely rare in the Balkan region, this is a significant finding.

In the Middle Ages, red glass was poorly transparent. To obtain a translucent ruby red colour in glass, the *flashing* technique was applied. Red flashed glass from the Dubrovnik cathedral was made of yellow glass dipped into a pot with red glass by a *cylinder blown sheet technique*, which was more effective than the *casting* or *crown technique*. This yielded a thin red layer on the surface and a thicker yellow layer beneath it. Red flashed glass also testifies that Dubrovnik followed the latest trends of Western Europe.

Stained glass from the Dubrovnik Cathedral may have been partially produced in Dubrovnik under Western European influence or imported from Western Europe. The cathedral's stained glass could have been made between the mid-14th century and 1440 (when Philip de Diversis mentioned the cathedral glass windows with representations of saints in his book). The cathedral windows were damaged in 1573 and the 1667 Dubrovnik earthquake caused their final destruction.

Povzetek

Vitraži so bili pomemben del poznosrednjeveške okenske arhitekture in so imeli tako dekorativno kot izobraževalno funkcijo. Dubrovnika republika je imela v poznem srednjem veku lastno proizvodnjo stekla, zabeleženi so tudi podatki o proizvodnji okenskega stekla. Dubrovnik se je v teku 14. in v prvi polovici 15. stoletja hitro razvijal. Odlomki vitražev iz raziskav dubrovnika katedrale so številni in različnih oblik, vendar fragmentirani in s skromno ohranjenimi poslikavami. Najdbe stekla so različnih barv: rumena, oker, rdeča, vijolična, zelena, rjavo vijolična, kobaltno modra in turkizna. Med materialom izstopa rdeče steklo (izdelano iz spodnje debelejšje brezbarvne ali rumene plasti stekla ter zgornje tanjše rdeče plasti). Črna poslikava je ohranjena na več fragmentih, vendar upodobitev ni mogoče rekonstruirati. Najdeni so bili tudi svinčeni odlomki okvirjev, v katere so bili vstavljeni koščki stekla, in ostanke bakrene žice za zaščito oken. Na nekaterih odlomkih

je opaziti linije malte, ki kažejo kako so bile plošče pritrjene na kamnite okvirje. Te najdbe dokazujejo načine vgradnje in zaščite vitražev v poznosrednjeveškem Dubrovniku, enako kot je bilo v navadi v največjih središčih tistega časa. Ker so arheološke najdbe vitražev na območju Balkana izjemno redke, gre za pomembne najdbe.

V srednjem veku rdeče steklo ni bilo povsem prosojno. Za ohranitev prosojne in sijoče rubinasto rdeče barve v steklu je bila uporabljena tehnika *flashing*. Rdeče steklo iz dubrovnika katedrale je bilo izdelano iz rumenega stekla, potopljenega v posodo z rdečim steklom s tehniko pihanja cilindra, ki je bila učinkovitejša od tehnike ulivanja ali krone. To je dalo tanko rdečo plast na površini in debelejšo rumeno plast pod njo. Rdeče steklo tako tudi dokazuje, da je Dubrovnik sledil najnovejšim trendom zahodne Evrope.

Vitraži iz dubrovnika katedrale je bili morda delno izdelani v Dubrovniku pod zahodnoevropskim vplivom ali pa uvoženi iz zahodne Evrope. Nastali so verjetno med sredino 14. stoletja in 1440 (ko je Philip de Diversis v svoji knjigi omenil steklena okna katedrale s podobami svetnikov). Okna katedrale so bila poškodovana leta 1573 dokončno uničenja pa je povzročil potres leta 1667.

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