Bohemian Garnets as Decorative Materials for Glass Vessels from the Late Sixteenth to Early Eighteenth Centuries

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The decorative craft of setting cut garnets on colorless or yellow glass vessels was invented by Claudius vom Creutz in the Imperial City of Nuremberg circa 1591. The legal context surrounding development of the technique can be traced through details set forth in imperial privileges (which were similar in effect to modern patents) from 1591, 1653, and 1714, and in relevant historical literature, particularly in books summarizing decisions of the Nuremberg administration and the imperial administration in Prague and Vienna.

Two glass vessels in the collections of the Bavarian National Museum in Munich and the Passau Glass Museum (Passau, Germany) are adorned with red stones using a technique attributed to Creutz. These were examined at the museums using a portable X-ray fluorescence analyzer, and it was found that rose-cut Bohemian garnets were affixed by layers of reddish brown or yellow lead glass to the bodies of the engraved glass goblets. This process entailed using heat to melt the lead glass, which simultaneously heated the garnets and the glass objects to temperatures below melting point. A second glass goblet from the Passau collection was decorated with red glass stones imitating Bohemian garnets.

Garnet-glass doublets, also designated as garnet-topped doublets, are known to most gemologists. These doublets consist of a thin layer or slice of almandine garnet fused to a body of colored glass. The color of the glass pavilion (e.g., green, blue, or yellow) dominates the color of the composite stone, and the red color of the garnet slice, representing the crown, has only little influence upon the doublet's coloration (Michel, 1926; Webster, 1964; Webster and Anderson, 1983). Such materials appeared in large quantities on the market in the 1920s but, according to Burdet (1925), were already being produced in the 1840s in the French Jura north of Geneva.

The present study describes another composite of glass and garnet, which was produced from the end of the sixteenth century to the first decades of the eighteenth century—more than two centuries before the manufacture of "modern" garnet-glass doublets started. In particular, this article describes the history and production of a composite consisting of faceted Bohemian garnets attached to glass goblets and glass beakers for decoration.

The Bavarian National Museum in Munich houses such a lidded goblet (figure 1), decorated with faceted red stones, described as garnets by Rückert (1982). It is stated that the goblet was donated to the museum's collection in 1960 from the estate of the Munich medical doctor Heinrich Brauser (1872–1959). The goblet was purchased by Brauser in 1926 from a Munich art gallery; for more details on Brauser and his glass collection, see Rückert (1962) and Pfeiffer (1977).

The goblet shows an engraving of a hunting scene with two hunters and several animals in a forest and is dated, based on the hunters' attire and the rose cuts of the garnets, to the 1630s or 1640s. Rückert (1982) also mentions that the decoration of glass objects with garnet is originally related to the Nuremberg artisan Claudius vom Creutz, who had, according to Rückert, obtained an imperial privilege for this technique in the first decade of the seventeenth century. Clues to the goblet's origin in Nuremberg and the

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Figure 1. Lidded goblet from the collection of the Bavarian National Museum in Munich, embellished with red Bohemian garnets. Inventory no. 60/74, height 17.7 cm. Photo by Bastian Krack; courtesy of Bavarian National Museum in Munich.

process developed by Creutz are also given by other authors (Bernt, 1950; Fuchs, 1959; Meyer-Heisig, 1963). In contrast, Żelasko (2014) dates the lidded goblet from the Munich collection to 1655 and assigns its origin to glassworks in Lower Silesia (now Poland), but without a detailed substantiation of this new provenance. Żelasko (2014) also incorrectly identified the red decorative materials as glass imitations, when they were in fact red garnets.

In an anthology of artists and craftspersons related to the Imperial City of Nuremberg (Grieb, 2007a), Claudius vom Creutz (also "von Creutz," "Kreutz," "Creuz," or "de la Croix" in various documents) is listed as a gemstone cutter and horologist. It is mentioned that he trained several cutters in Nuremberg, and he is described in a portrait (figure 2) as the first garnet setter (*Cranaten Sezer*) in that city. The index of artistic crafts in Grieb (2007b) mentions within the group of gemstone cutters, seal engravers, and goldsmiths several professions that still exist such as diamond cutter, ruby cutter, and garnet cutter, but also "garnet rose setter," a craft that is obsolete.

The present article seeks to elucidate the use of red Bohemian garnet to decorate glass objects, a technique invented by Creutz in the latter sixteenth century. Furthermore, the authors present a brief overview of Creutz and the imperial privileges granted to him and his successors. Such imperial privileges are compara-

Figure 2. Portrait of gem cutter Claudius vom Creutz, designated as the first garnet setter in the city of Nuremberg. Copper engraving by Johann Paul Zieger, Nuremberg, seventeenth century. Courtesy of the Germanic National Museum in Nuremberg (signature MP 5071, Kapsel-Nr. 72).

Figure 3. Extraction and processing of Bohemian garnets in the nineteenth century: (1) digging at the surface, (2) retrieving garnet-bearing soil or gravel from deeper levels and sieving, (3) washing to remove soil, (4) sorting, (5) cutting, (6) polishing, and (7) a view of the cutting table. From Gareis (1884).

ble to modern patents. However, these privileges were granted by grace of the emperor rather than by general law and were specific to each invention and inventor. For this study, the method applied for attaching garnets to the glass substrate was also examined by microscopic and analytical techniques and is explained with the help of these results.

The use of Bohemian garnet for jewelry and other decorative objects is known since the migration period in Europe from about 400 to 600 CE (e.g., Quast and Schüssler, 2000; Gilg et al., 2015). Most garnets originate from secondary deposits, where they can be easily removed from the garnet-bearing soil or gravel. The methods for digging and cutting at the end of the nineteenth century (illustrated in figure 3) appear to be more or less identical to the techniques applied in the centuries before.

CLAUDIUS VOM CREUTZ

Sources. Two main sources review original documents related to events in the life of Creutz: the decisions of the council of the Imperial City of Nuremberg

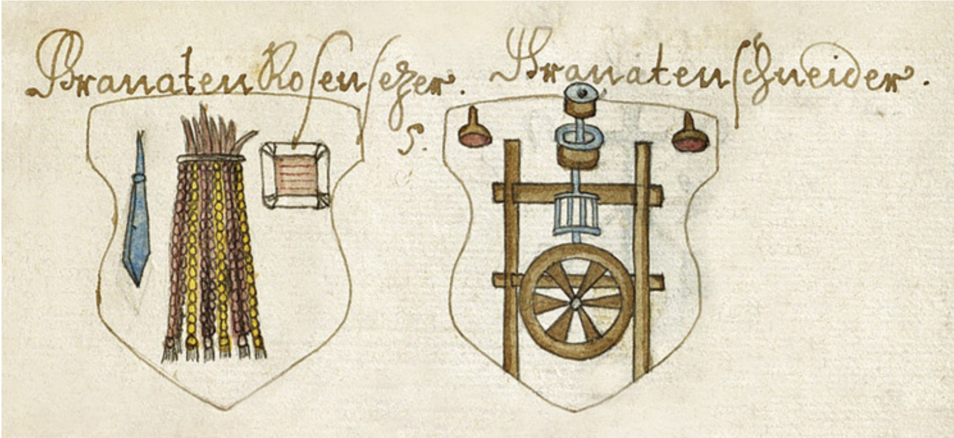


Figure 4. Coat of arms for the crafts of the "garnet rose setter" (left) and "garnet cutter," from the handwritten descriptions of all crafts in the Imperial City of Nuremberg around 1700. From Von Ursprung und Herkom[m]en samt Beschreibung aller Hand Wercker in der Stadt Nürnberg *(ca. 1700). Courtesy of the Germanic National Museum in Nuremberg (signature Merkel Hs 2° 981).*

(Hampe, 1904) and the yearbooks of the art historical collections of the imperial family (Graf zu Trautmannsdorff-Weinsberg, 1889, 1894; Graf von Abensberg und Traun, 1898). An anonymous compilation of all crafts in Nuremberg at the time (*Von Ursprung und Herkom[m]en samt Beschreibung aller Hand Wercker in der Stadt Nürnberg*, ca. 1700) dedicates one page (see figure 4) to Creutz and the professions of garnet rose setter and garnet cutter. Two handwritten copies of the treatise are kept in different archives in Nuremberg (see also a second copy of the book, titled *Von Ankunft und Herkommen aller Handwerker, so in der Stadt und Landwehr Nürnberg wohnhaft*, 1719). A file of Creutz's privileges with documents from 1591 to 1600 is kept in the Austrian State Archives in Vienna.[1] Further dates from his life are found in Thieme (1913) and on the "Astronomy in Nuremberg" website (www.astronomie-nuernberg.de).

In Brief

- Rose-cut Bohemian garnets were attached as decorative materials to the surfaces of engraved glass vessels by thin layers of low-melting-point lead glass.
- The technique was invented around 1590 by Claudius vom Creutz in Nuremberg and continued to be used through the first decades of the eighteenth century.
- Legal rights governing use of the technique, known as privileges, were granted to citizens of Nuremberg by Emperor Rudolf II and his successors.

[1]File: Creutz Claudius, Nürnberg, erhält das Privileg böhmische Granaten zu färben und zu schneiden (1591). Signature: AT-OeStA/HHStA RHR Grat Feud Gewerbe-, Fabriks- und Handlungsprivilegien 2-2-14.

Summary of Events (see table 1 and Schmetzer et al., 2024). The first document to mention Creutz in the Imperial City of Nuremberg is dated 1572 and refers to a textile merchant. A first marriage was reported in the same year, and a second is known from 1588. Creutz was Calvinist, and several documents mention that he descended and migrated from France, though his place and date of birth are unknown.

TABLE 1. History of garnet setting on glass objects.

1572	C. vom Creutz is mentioned as a textile merchant in the city of Nuremberg
1584, 1588, 1589	Various privileges of the city of Nuremberg are granted to Creutz
1591	The privilege of Emperor Rudolf II is granted to Creutz
1598	Privileges of the city of Nuremberg are extended
1600	The privilege of Emperor Rudolf II is extended
1604	Death of Creutz
1610s to 1620s	Transfer of the imperial privilege to V. Fischer, whose son J.T. Fischer later sells the rights to G. Schürstab (all from Nuremberg)
1653	Renewal of the privilege by Emperor Ferdinand III to G. Schürstab
1714	Renewal of the privilege by Emperor Karl VI to J.J. Vogel and J.P. Rotgängel of Nuremberg
1720	Five master craftspersons are still working in Nuremberg as garnet rose setters

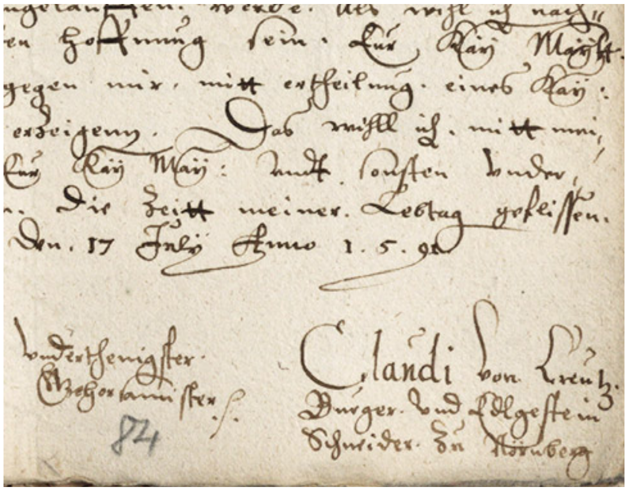


Figure 5. Signature from the petition of Creutz, "citizen and gem cutter from Nuremberg," to Emperor Rudolf II. The petition is dated July 17, 1591. Courtesy of the Austrian State Archives in Vienna (see footnote 1).

In 1584, Creutz applied for a privilege related to a tool for cutting Bohemian garnets, which was granted by the Nuremberg Council. At the time, the issue of local privileges by a city was an exception in the history of laws, at least in Germany. A further privilege was issued in 1588 for the cutting of rock crystal and jasper. The technical details of these inventions and their advancements to the state of art are unknown. A third local privilege, issued in 1589, referred to the "setting of rose cut garnets."

In May 1591, Creutz petitioned Emperor Rudolf II (1552–1612, r. 1576–1612), residing in Prague, to grant a privilege for the same topic (figure 5). The application mentions four steps of production: cutting, composing, setting, and melting (i.e., attaching by melting an intermediate lead glass fixation layer) of Bohemian garnets on colorless or yellowish glass. Further details about the technique are not given, but it is mentioned that examples of embellished glasses accompanied the petition. The privilege was granted by grace of the Holy Roman Emperor in August 1591 for a term of eight years.

Between 1598 and 1600, Creutz petitioned the Nuremberg Council and the emperor for extensions of his privileges, and the Nuremberg Council also intervened on his behalf at Prague. Extensions were granted from the Nuremberg Council in 1598 and the emperor in 1600, whereby Creutz was even able to extend the privilege to his wife and sons and to include a cutting tool.

Creutz educated several apprentices in his techniques for cutting and setting garnets. If these apprentices wanted to work independently, they could attain licenses against payment. Creutz took action several times against infringements of his rights, and Nuremberg craftspersons who copied his art and techniques were forced to pay penalties (Pohlmann, 1961).

It is said that Creutz became wealthy from his craft but died poor due to an extravagant lifestyle. After his death in 1604, his privileges were transferred to his three underage sons and their rights were exercised by their guardians, according to numerous documents from 1605 to 1611.

SUCCESSORS OF CREUTZ

Sources. A file containing documents about the extension of Creutz's privilege to Georg Schürstab in 1653 is available from the Austrian State Archives in Vienna,[2] and a document related to this legal act is preserved at the Germanic National Museum in Nuremberg[3] (figure 6). A further extension was issued in 1714 for Johann Jacob Vogel and Johann Paul Rotgängel. The file for this act is found in the Austrian State Archives in Vienna,[4] and a related document is kept in the Historical Archives of the City of Nuremberg[5] (figure 7).

Summary of Events (see table 1 and Schmetzer et al., 2024). After Creutz's death, the rights were transferred to Valentin Fischer, who had been taught the technique of cutting and setting garnets by Creutz. Upon Fischer's death in 1621, the rights were inherited by his son Johann Thomas Fischer, who sold the privilege to Georg Schürstab at Nürnberg. In 1653, the privilege was renewed by Emperor Ferdinand III (1608–1657, r. 1637–1657). A further extension of the privilege was issued by Emperor Karl VI (1685–1740, r. 1711–1740) for Johann Jacob Vogel and Johann Paul Rotgängel in 1714.

The detailed text of the imperial privilege from 1714 shows a broad application to all glass objects

[2] File: Schürstab Georg zu Nürnberg, erhält Privileg Böhmische Granaten zu versetzen (1653). Signature: AT-OeStA/HHStA RHR Grat Feud Gewerbe-, Fabriks- und Handlungsprivilegien 9-2-9.

[3] File: Privileg für Georg Schürstab (1653). Signature: SB-URO Or. Perg. Dated October 1, 1653.

[4] File: Vogel Johann Jakob und Rothgängel Johann Paul erhalten Privileg die böhmischen Granaten zu schneiden, zu versetzen und zu verkaufen (1714). Signature: AT-OeStA/HHStA RHR Grat Feud Gewerbe-, Fabriks- und Handlungsprivilegien 11-2-3.

[5] File: Kaiserliches Privileg Vogel/Rothgängel von (1714). Signature: A 1 Nr. 1714-06-10 GF.

Figure 6. Emperor Ferdinand III's privilege for Georg Schürstab, 1653. Courtesy of the Germanic National Museum in Nuremberg (see footnote 3).

decorated with Bohemian garnet, including their production and commercial distribution. The privilege was valid for all principalities and imperial cities within the Holy Roman Empire. All princes, dignitaries, and officials were requested to uphold the rights of privilege holders. Penalties for infringements of these rights were also quoted. Such rights could be transferred to all descendants or heirs of the owners.

Figure 7. First page of the privilege of Emperor Karl VI for Johann Jacob Vogel and Johann Paul Rotgängel, 1714. Courtesy of the Historical Archive of the City of Nuremberg (see footnote 5).

Figure 8. Lidded goblet from the collection of the Bavarian National Museum, embellished with red Bohemian garnets. Inventory no. 60/74, height 17.7 cm. Photos by Bastian Krack; courtesy of Bavarian National Museum in Munich.

It is mentioned that the privilege was intended to deter the production of objects of low quality.

If we compare the various texts of documents issued from the late sixteenth to early eighteenth centuries, it is worth mentioning that the description of the technique applied is almost identical to Creutz's original wording, and no further technical details were added in later applications or privileges. Within these descriptions, no details are provided on how the faceted Bohemian garnets were affixed to the glass substrate.

In 1720, there were still five master craftspersons with the title of "garnet rose setter" working in Nuremberg, but this profession became extinct in the second half of the eighteenth century (Gatterer, 1790). The decline of garnet setting on glassware coincided with the decline of the art of glass engraving in Nuremberg, as described by Hampe (1919).

MATERIALS AND METHODS

Glass goblets and beakers embellished with Bohemian garnets are extremely rare. We are aware of the sample owned by the Bavarian National Museum, inventory no. 60/74 (figure 1 and figure 8; see Rückert, 1982; Żelasko, 2014) and a glass beaker preserved in the Passau Glass Museum, inventory no. Hö 67867 (figure 9). This beaker was described by Żelasko (2014) as originating from glassworks in Lower Silesia and dated to 1655. The beaker was purchased in 1993 at an art auction, according to Peter Höltl from the Passau Glass Museum. The decoration of the Munich goblet originally consisted of 60 red stones on the body and 45 red stones on the lid, while the decorative pattern of the Passau beaker featured 44 red stones. These two decorated and engraved glass objects were examined in the present study.

Another glass goblet associated with the technique developed by Creutz (Stehlíková, 2004) is preserved in the Czech National Museum in Prague, but this example was not available for examination.

The Passau Glass Museum also houses numerous examples of goblets and beakers set with red (and also green) decorative materials, some of which are rose-cut red glass imitations of garnet. For comparison, we selected one of these samples, a lidded goblet, inventory no. Hö 71145 (figure 10), which was attributed by Żelasko (2014) to glassworks in Lower Silesia and dated to the first quarter of the eighteenth century.

The three decorated glass vessels were examined on the museum premises in Munich and Passau. In an initial visual inspection, we numbered each garnet and the positions of missing decorative materials

Figure 9. Beaker from the collection of the Passau Glass Museum, decorated with red Bohemian garnets. Inventory no. Hö 67867, height 9.8 cm. Photos courtesy of P. Höltl, Passau Glass Museum.

Figure 10. Lidded goblet from the collection of the Passau Glass Museum, embellished with red and green imitation stones made of lead glass. Inventory no. Hö 71145, height 8.5 cm. Photo courtesy of P. Höltl, Passau Glass Museum.

on photos of the glass objects, noting particularly the gem cutting styles (see figures 8 and 9). Next, the three samples were chemically analyzed using a portable Bruker Tracer III-SD energy-dispersive X-ray fluorescence (EDXRF) analyzer (figures 11 and 12). The instrument is equipped with a rhodium anode, a silicon drift detector with a resolution of 147 eV at 10,000 cps, and a portable vacuum pump system. The spot size of the primary beam is about 2 × 3 mm. We used two analytical conditions for the measurement. The first setup, with an accelerating voltage of 15 kV and a beam current of 25 μA under vacuum, was used to analyze the light elements of interest (magnesium to iron; note that sodium cannot be detected with this method and could also be present in the glasses). The second setup was used for the ex-

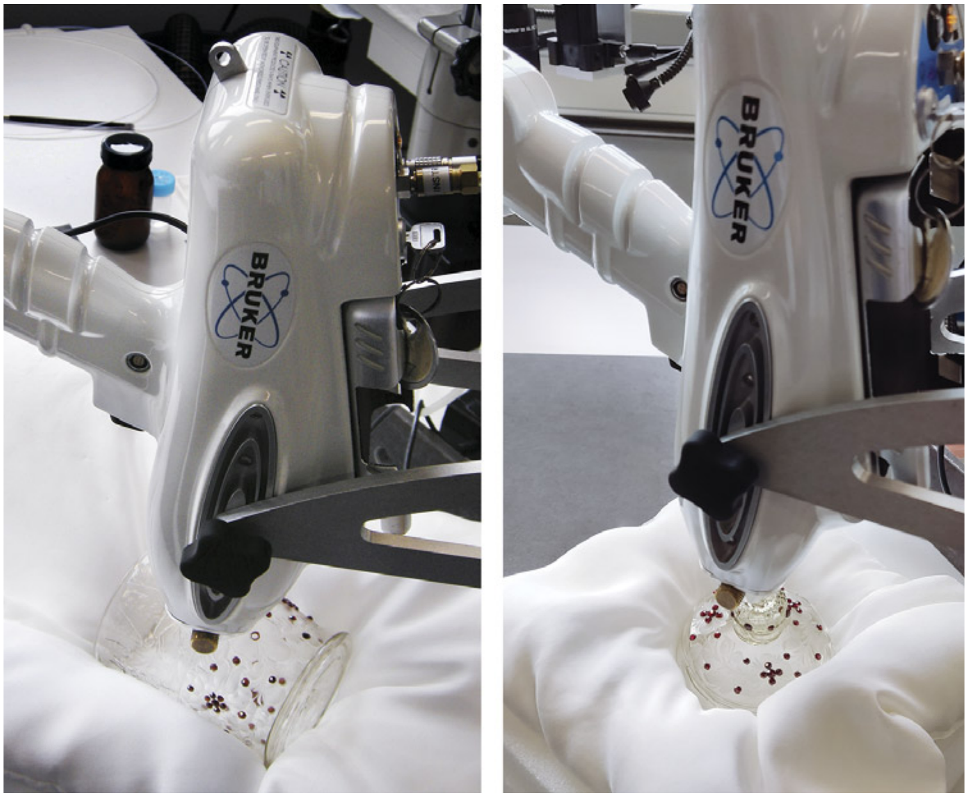


Figure 11. Examination of the lidded goblet in the research and conservation rooms of the Bavarian National Museum using a portable X-ray fluorescence analyzer. Photos by K. Schmetzer.

amination of heavier elements with 40 kV and 30 µA using a yellow filter (thicknesses of 0.001 mil titanium and 0.012 mil aluminum) that eliminated the weak Bragg peaks in the spectra. The acquisition time was 30 seconds for each spectrum. We measured twelve garnets in Munich and eight garnets in Passau, as well as three red glass imitation stones on the goblet from Passau (figure 10).

In some areas of the glass objects, the red decorative materials were lost, but residues of a reddish brown (Munich) or yellow (Passau) fixation layer were left behind. Therefore, we were able to perform a three-part series of examinations, in which the primary X-ray beam was directed at (1) the glass goblets or beaker alone, (2) the glass and residues of the fixation layers, and (3) the glass and the fixation layers

Figure 12. Examination of the beaker (left) and the lidded goblet (right) in the exhibition rooms of the Passau Glass Museum using a portable X-ray fluorescence analyzer. Photos by K. Schmetzer.

together with the red decorative materials. Three to four such rounds of examination were performed for all three engraved glass vessels.

In addition to X-ray fluorescence analysis, we examined the garnets, the fixation layer, and the underlying glass of the Munich goblet using Olympus BX51 and Leica M205 C microscopes and a portable Enwave EZRaman-N-785-B spectrometer. The spectrometer works with a fiber-optic system; the laser wavelength applied was 785 nm at an energy of 300 mW, with a measurement range from 100 to 3300 cm^{-1} and a spectral resolution of 7 cm^{-1}. The acquisition time was 50 seconds for each spectrum, and we always averaged 10 measurements. Again, several series of Raman spectra were obtained for (1) the glass goblet alone, (2) the glass and residues of the fixation layers, and (3) the glass and the fixation layers together with the red decorative materials. We analyzed the same spots that had been measured by EDXRF.

Finally, to test the Munich goblet's reddish brown fixation layers for stability and the presence of organic materials, these layers were brought into contact with a hot needle and examined microscopically. Again we examined the same spots measured by EDXRF.

RESULTS

Examination of the Lidded Goblet in Munich. *Engraved Glass Body*. A microscopic examination of the lidded goblet from the Munich collection showed that the edges of the glass engraving are slightly rounded. This resembles previous observations made on engraved glasses that have been heat treated after engraving, commonly known as fire polishing of glass.

Decoration. The decoration of this goblet consists of transparent rose-cut stones of either groups of 4 mm stones surrounded by 3 mm stones or single 3 mm

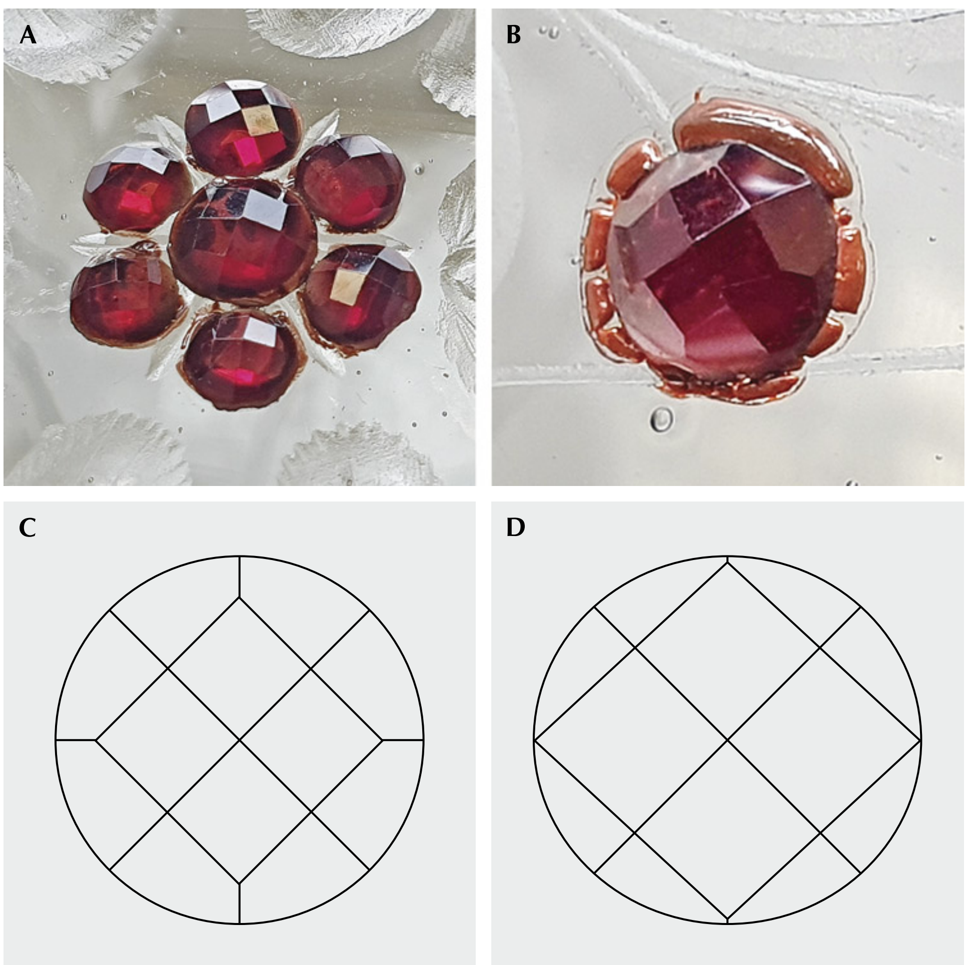


Figure 13. A and B: Rose-cut garnets decorating the lidded goblet from the collection of the Bavarian National Museum. The diameters are 4 mm (center stone) and 3 mm (surrounding stones) in A and 3 mm in B; photos by H.A. Gilg. C: Diagram of the most common cut observed for the garnets in Munich. D: A small proportion of the garnets showed somewhat larger central squares.

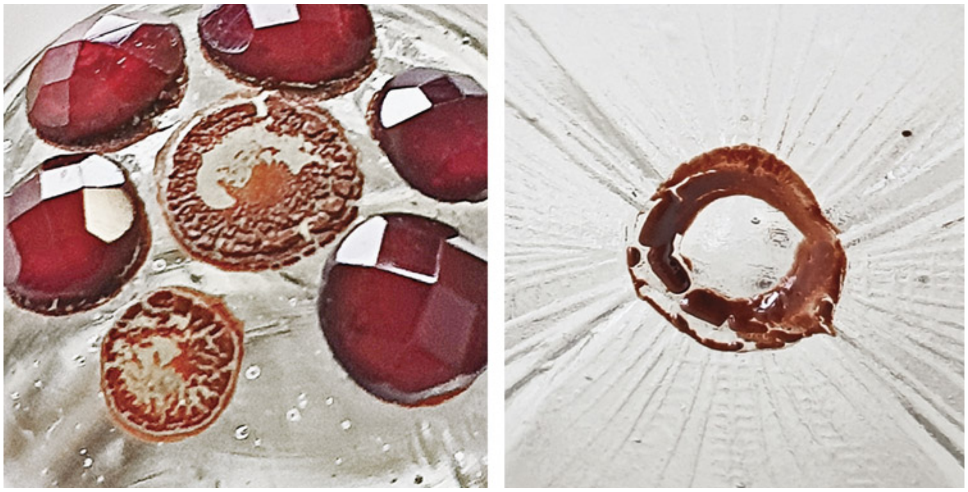


Figure 14. Residues of the reddish brown fixation layer on the glass substrate of the lidded goblet in Munich; the diameters of the reddish brown residual materials measure 4 and 3 mm (left, center and bottom, respectively) and 3 mm (right). Photos by H.A. Gilg.

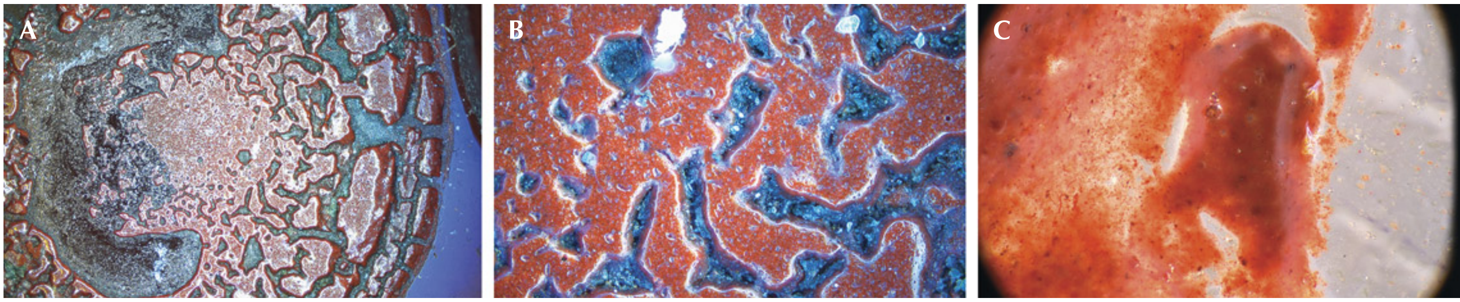
stones (figure 13, A and B). The cut of all the stones was identical, with four-fold symmetry—i.e., four square facets in the center, each adjacent to four outer quadrilateral facets (figure 13, A–C). In general, the girdles of the rose-cut stones were rounded. Three stones showed an identical cut but different facet proportions, with relatively large central squares and relatively small outer facets (figure 13D). No inclusions or indications of heat treatment were observed in the red decorative materials at the magnification applied (up to 100×).

Fixation Layer. On the surface of this goblet, especially at locations with missing red decorative garnets, we observed residual masses of a reddish brown substance that was partly transparent and partly opaque (figure 14). The residual material showed an uneven distribution on the surface of the underlying glass substrate. The same reddish brown substance was also observed between the rim of the red decorative stones and the underlying glass (figure 13B), especially in views from the interior of the beaker through the vessel's glass wall. It seemed as if this material was ejected from a gap between the glass substrate of the goblet and the red decorative stones.

Microscopic examination showed details of such flow structures (figure 15, A and B). At most locations, the thickness of the reddish brown layer was quite variable, with a somewhat uneven color intensity (figure 15C). This impression was caused not only by the variable thickness of the layer but also by small opaque particles unevenly dispersed within this layer. The same observation was made at locations where red decorative stones remained (figure 16). The reddish brown layers as a whole showed no reaction upon contact with a hot needle, which indicates that no organic volatile matter was part of the residual fixation layers.

Raman Analysis. The Raman spectra of the rose-cut stones showed, especially in comparison with standard spectra of Bohemian chromium pyropes (from

Figure 15. A and B: Microscopic images of the reddish brown fixation layer on the glass substrate of the lidded goblet in Munich showing flow structures. C: Within the groundmass of lead glass, small hematite particles are finely dispersed. Photomicrographs by H.-J. Ranz; fields of view 3.5 mm (A), 0.9 mm (B), and 1.8 mm (C).



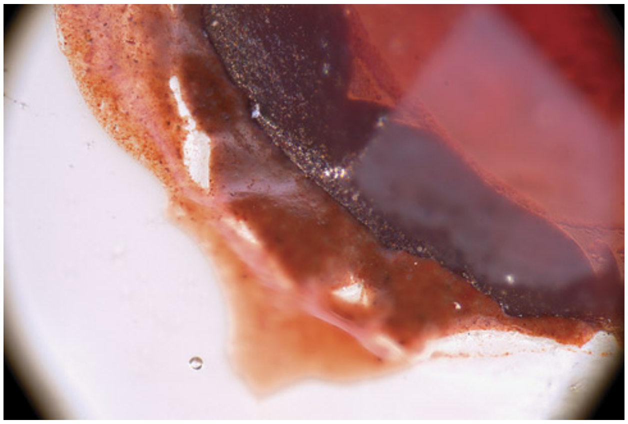


Figure 16. Decorative Bohemian garnet fixed to the colorless glass substrate of the lidded goblet in Munich. The reddish brown fixation layer is found in the gap between the garnet and the glass substrate, but also on the glass substrate outside of the garnet. Photomicrograph by H.-J. Ranz; field of view 4.47 mm.

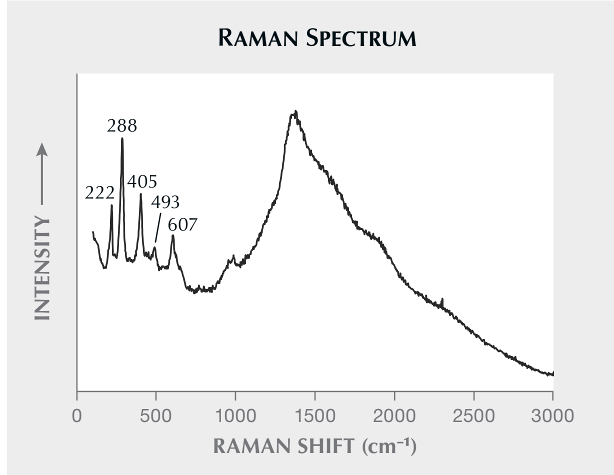
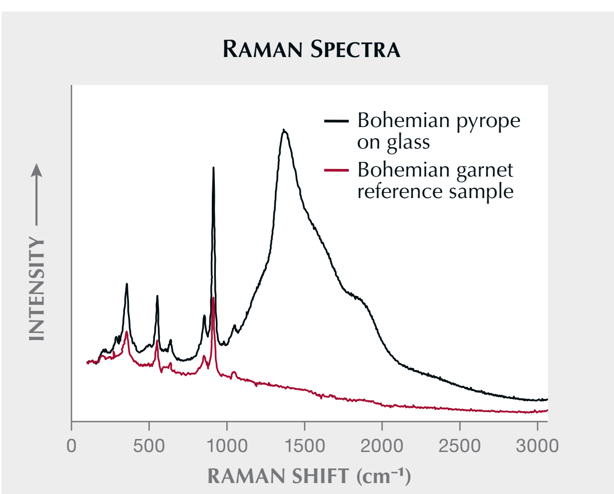


Figure 18. Raman spectrum of the reddish brown fixation layer on the Munich glass substrate. The different maxima (labeled) were assigned to finely dispersed hematite particles; the broad maximum at 1500 cm^{-1} is also observed in the Raman spectrum of the underlying glass substrate without any additional fixation layer or garnet.

the Bohemian Midlands, in the collections of the authors) taken with the same instrument, that all red stones measured were titanium-bearing chromium pyrope (figure 17; see Gilg and Gast, 2016). Furthermore, Raman spectroscopy revealed that the fixation layers contain hematite (figure 18), recognized by the irregularly distributed reddish brown opaque particles seen in the microscope.

Figure 17. Raman spectrum of a Bohemian pyrope on glass and a spectrum of a standard sample of Bohemian garnet. The broad maximum at 1500 cm^{-1} is also observed in the Raman spectrum of the underlying glass substrate without any additional fixation layer or garnet.



X-Ray Fluorescence Analysis. The X-ray fluorescence spectra recorded from all three vessels showed no significant differences for each vessel between various locations examined on the same decorated glass. This indicates the use of a uniform substance as the fixation layer and a uniform material applied on top of this substance for embellishment.

The spectra of the glass of the engraved goblet from Munich show the signals of silicon, potassium, and calcium as main components and traces of aluminum, phosphorus, titanium, manganese, iron, copper, zinc, strontium, rubidium, and zirconium (figure 19). Compared to this potassium-calcium-glass, the fixation layer was distinguished by additional characteristic lines of lead and iron and weaker lines of tin and copper. In addition, the red decorative material shows an enrichment of magnesium, aluminum, titanium, chromium, and iron.

Examination of the Beaker in Passau. *Decoration*. This beaker shows red rose-cut garnets with a diameter of 3 mm each (figure 20, left). The cutting style is identical to the rose cuts observed in the Munich lidded goblet, with slightly different proportions—i.e., somewhat larger central squares compared to the outer quadrilateral facets (figure 20, right).

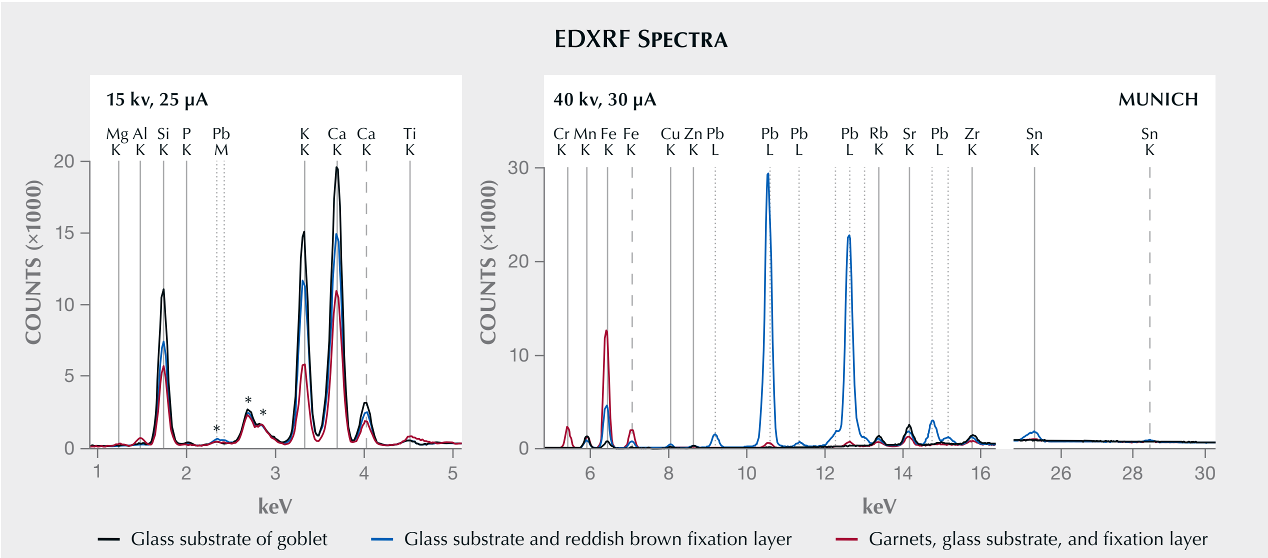


Figure 19. EDXRF spectra of the lidded goblet from the Bavarian National Museum. The spectra were recorded with two different experimental setups: 15 kV and 25 µA (left) and 40 kV and 30 µA (right). Solid gray lines indicate the positions of Kα X-ray lines, dashed gray lines represent the positions of Kβ X-ray lines, and dotted gray lines represent the positions of L and M X-ray lines. The peaks labeled with an asterisk originate from the X-ray tube (Rh) and from the collimator (Pd).

Fixation Layer. The beaker from the Passau glass collection also showed some residual material of a fixation layer. These masses, in contrast to the fixation layer observed on the Munich lidded goblet, were an intense yellow and showed an uneven, roughened undulating surface with a bubble-like texture (figure 21).

X-Ray Fluorescence Analysis. The spectra from the beaker from the Passau Glass Museum again revealed the presence of a potassium-calcium glass. In the yellow fixation layer, the elements lead, tin, copper, and antimony were also present (figure 22). Compared to the spectra of the glass substrate with the fixation layer, the red faceted rose-cut stones indicate an enrichment of magnesium, aluminum, titanium, chromium, and iron.

Examination of the Lidded Goblet in Passau. *Decoration and Fixation Layer*. This goblet, decorated with red and green glass imitation stones, showed no fixation layer between the decoration and the underlying glass substrate.

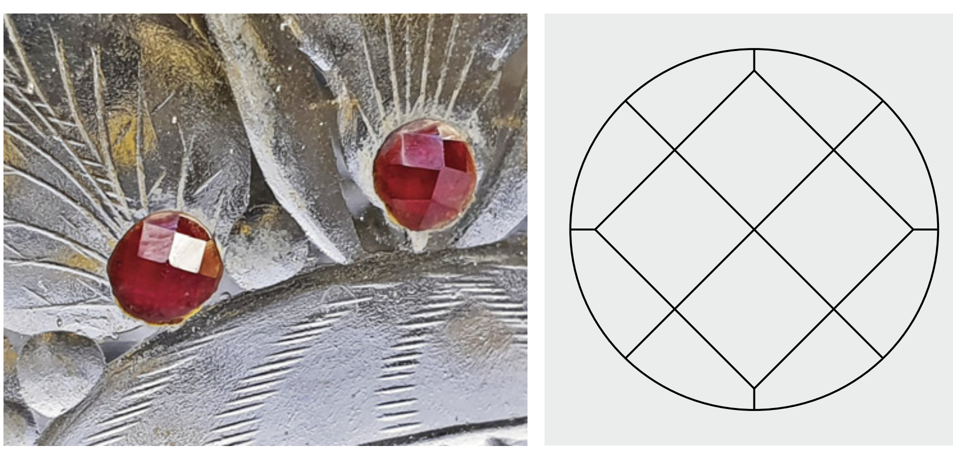


Figure 20. Left: Rose-cut garnets decorating the beaker from the collection of the Passau Glass Museum, 3 mm in diameter. Photo by H.A. Gilg. Right: Diagram of the common cut observed for the garnets in Passau.

Figure 21. Residues of the yellow fixation layer on the glass substrate of the beaker in Passau showing an uneven surface with a bubble-like texture; the yellow residual materials measure about 3 mm in diameter. Photos by H.A. Gilg.

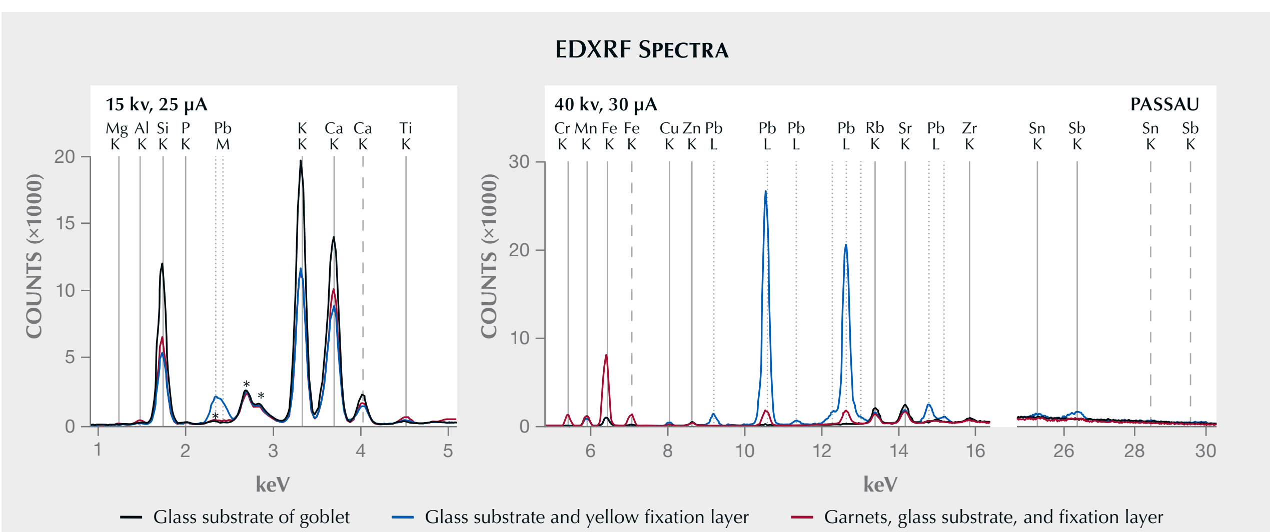
X-Ray Fluorescence Analysis. This vessel was different from the other two samples examined. Again, the spectra (not given here) characterize a potassium-calcium glass, but with an enrichment of arsenic. Compared to the underlying glass, the red decorative glass materials show an enrichment only of lead.

DISCUSSION

Identification of Materials. The examined glass vessels consist of potassium-calcium glasses, which are typical for the seventeenth and eighteenth centuries (see Wedepohl, 2003). The hot needle test applied to the reddish brown fixation layer of the Munich lidded goblet and the absence of characteristic C-H vibration lines in the Raman spectrum indicate that no organic components were present in the residues of the fixation layer. In contrast, the Raman spectrum combined with the microscopic examination shows the presence of small hematite particles, which are responsible for the coloration of this layer that was consequently identified as a hematite-bearing lead glass.

According to their actual weight percentage of lead oxide, lead glasses reveal a melting point in the range of 700°–800°C, compared to a melting point of "ordinary" potassium-calcium glasses at about 1100°C (Wedepohl, 2003; Stern and Gerber, 2004). For the red decorative stones, a fixation layer of lead glass with a lower melting point was obviously applied, which did not affect or damage the underlying

Figure 22. EDXRF spectra of the beaker from the Passau Glass Museum. The spectra were recorded with two different experimental setups: 15 kV and 25 µA (left) and 40 kV and 30 µA (right). Solid gray lines indicate the positions of Kα X-ray lines, dashed gray lines represent the positions of Kβ X-ray lines, and dotted gray lines represent the positions of L and M X-ray lines. The lines labeled with an asterisk originate from the X-ray tube (Rh) and from the collimator (Pd).



glass substrate or the decorative material. This result also applies to the Passau beaker, which shows the application of a yellow lead glass as the fixation layer. The coloration of the reddish brown lead glass layer in the Munich goblet is due to admixtures of small particles of hematite pigments. The yellow coloration of the lead glass layer in the Passau beaker is assumed to be due to the observed traces of tin- and antimony-bearing pigments. Such pigments, in general, are responsible for a yellow coloration of historical glasses (Wedepohl, 2003). Without hematite, the lead glass in the Munich goblet would most likely also show a yellow coloration, but in that case the presence of hematite is dominant for its reddish brown coloration, and the yellow color component is not visible.

The red decorative stones on the surface of the lidded goblet from Munich and the beaker from Passau were identified as Bohemian pyrope. The X-ray fluorescence spectra show—compared to the spectra of the underlying glass substrate and the lead glass fixation layer—an enrichment of magnesium and aluminum, two of the main components of pyrope (silicon is always present in the glasses and a silicon peak is always seen in the spectra of all materials examined). In addition, the spectra of the red stones show an enrichment of titanium and iron and especially chromium, which is considered the main color-causing trace element of red Bohemian pyrope garnet (Amthauer, 1976; Gilg et al., 2015; for a recent summary of properties of Bohemian garnet, see Hanus et al., 2022).

The red decorative materials applied to the lidded goblet in Passau were identified as lead glass.

Production Techniques. The results described above offer some clues to Creutz's original production technique. Theoretically, there are many possible methods for placing red garnets on glass substrates, but many of these would not produce the properties determined for the glass vessels in Munich and Passau. Consequently, we are only discussing the technique and its variations that are consistent with the results of the visual and chemical examination of the samples.

For the decoration of engraved glass vessels, rose-cut Bohemian garnets were attached with a fixation layer to the outer surface of the underlying glass substrates. At the end of the manufacturing process, after cooling of the heated goblet or beaker, the final fixation layer consisted of a lead glass with a lower melting point than that of the main glass body. In order to hide the fixation layer in the Munich example, finely grained hematite particles (or other iron-bearing oxides or hydroxides that turned to hematite after heating) were added to the lead glass, imitating the coloration of Bohemian pyrope.

It has been known for centuries that it is possible to anneal pyrope at an elevated temperature range of about 700°–800°C without decomposition. This knowledge was publicly available since at least the late seventeenth century in the famous book by Kunckel (1689) about glass technology. According to more recent studies, the structure of Bohemian pyrope is stable to at least 1000°C (Zboril et al., 2003).

For the attachment of garnets to the main glass substrate, it can be assumed that finely ground lead glass frit, possibly with an admixture of finely ground hematite, was mixed with water or with an organic binder such as gum arabic or tragacanth, which have been used for pigments since the Middle Ages. After drying of the intermediate fixation layer between the garnets and the glass, the garnets would be placed in the desired positions on the glass body. After heat treatment of the complete glass body and melting of the fixation layer, the organic binder would completely escape by oxidation and vaporization, leaving a lead glass layer with melted or blister structures (for this production step, see Brepohl, 1983).

A variant of this scenario is to add a binder to finely ground lead glass frit and cover the flat base of the garnet roses with that mixture. After the garnets have been prepared with such a layer and that layer has dried, placing them on a heated glass body would cause the dried fixation layer to melt after evaporation of the binder, in that way fixing the garnets upon cooling. Further variants are conceivable, especially if we consider the different textures of the residual fixation layers of the vessels preserved in Munich and Passau.

The steps described for such a production process are consistent with the four steps mentioned in the privileges of Creutz and his successors:

1. Cutting and faceting of the garnets
2. Connecting the garnets with a mixture of lead glass and a binder
3. Setting the garnets on the glass substrate
4. Melting the mixture of lead glass and binder by heat treatment

The difference between the two variants described is based upon the method of melting the fixation layer, a mixture of finely grained lead glass and a binder. The two alternatives are:

- Heating the glass body of the goblet or beaker together with the intermediate fixation layer and the garnets, after the fixation layer had dried between the glass substrate and the garnets
- Heating the glass body of the goblet or beaker to melt the fixation layer already adhered to the rose-cut garnets

Obviously, different artisans applied different recipes for the mixture used as a fixation layer, and these recipes were closely guarded trade secrets. The temperatures applied for the melting processes might have varied according to the artist, and even the same artist could have worked with slightly different temperatures, if we consider the ability to measure and adjust temperatures in the seventeenth century. These slightly different production processes allow us to understand some properties of the final products such as the different coloration of the final fixation layer on the surface of the Munich lidded goblet and the Passau beaker. The glass objects, their engraving, and their subsequent embellishment could have been produced by different craftspersons in Nuremberg or elsewhere.

CONCLUSIONS

The documents available in archives in Vienna and Nuremberg indicate the use of a process to decorate glass substrates with rose-cut Bohemian garnets from the end of the sixteenth century to the first decades of the eighteenth century. This process was invented and developed by Claudius vom Creutz in Nuremberg, who first obtained privileges from the Imperial City of Nuremberg and later from Emperor Rudolf II. Glass objects produced with this technique are extremely rare, but two glass vessels preserved in museums in Munich and Passau were available for examination.

On the lidded goblet from the Munich museum and the beaker in Passau, Bohemian garnets are attached by a fixation layer, consisting of lead glass with admixtures, that was melted by careful heating processes. A third glass vessel examined, a lidded goblet in Passau, proved to have rose-cut glass, not garnets. It is unknown whether glass objects other than goblets and beakers were decorated with Bohemian garnets. Such objects would also fall within the wording used within the imperial privileges to describe the process. The nature of "garnet doublets" mentioned in inventories in the late seventeenth and early eighteenth centuries (Brackenhofer, 1683; *Museum Wolfianum*, 1714) is unclear. In the seventeenth century, "doublets" generally consisted of an upper and lower part of the same stone, with a colored layer in between (*Praktisches Handbuch für Künstler...*, 1793).

These two glass vessels from Munich and Passau were prepared with the same type of production technique, which is clearly revealed by the examination of the samples. The most common feature is the fixation layer of lead glass in between the garnets and the glass substrate of the vessels. The chemical differences between the two layers and the presence of an admixture of hematite in the fixation layer of the lidded goblet in Munich indicate different manufacturers and possibly production in different cities or locations.

Żelasko (2014) mentioned invoices for glasses decorated with garnets, which were produced in Lower Silesia in the seventeenth century. This indicates that the method was also applied in regions or cities beyond Nuremberg. It is documented that infringements of the privileges of Creutz were pursued in Nuremberg, but it is unknown whether the privileges were also effective in distant areas of the Holy Roman Empire with industrial glassworks.

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REFERENCES

Amthauer G. (1976) Kristallchemie und Farbe chromhaltiger Granate. *Neues Jahrbuch für Mineralogie Abhandlungen*, Vol. 126, No. 2, pp. 158–186.

Bernt W. (1950) *Altes Glas*. Prestel Verlag, Munich, p. 56.

Brackenhofer E. (1683) *Musaeum Brackenhofferianum: das ist ordentliche Beschreibung aller, so wohl natürlicher als kunstreicher Sachen, welches sich in weyland Hrn. Eliae Brackenhoffers, gewesenen Dreyzehners bey hiesiger Statt Straßburg, hinterlassenen Cabinet befinden*. Johann Wespern, Straßburg, p. 23.

Brepohl E. (1983) *Kunsthandwerkliches Emaillieren*, 3rd ed. VEB Fachbuchverlag, Leipzig, p. 31.

Burdet G. (1925) *Étude historique sur la pénétration et le développement de l'industrie lapidaire sur le plateau de Septmoncel et dans la région de Saint-Claude*. Morez, France, p. 57.

Fuchs L.F. (1959) Zum Tode Dr. Heinrich Brausers. *Weltkunst*, Vol. 29, No. 24, p. 23.

Gareis A. (1884) Die Granatindustrie in Böhmen. *Illustrierte Welt*, Vol. 32, No. 5, pp. 51–52.

Gatterer C.W. (1790) *Technologisches Magazin*, Erster Band, Erstes und Zweytes Stück. Andreas Seyler, Memmingen, p. 185.

Gilg H.A., Gast N. (2016) Determination of titanium content in pyrope by Raman spectroscopy. *Journal of Raman Spectroscopy*, Vol. 47, No. 4, pp. 486–491, http://dx.doi.org/10.1002/jrs.4838

Gilg H.A., Gast N., Hyršl J. (2015) Chromium pyropes from Bohemia: Characterization and identification in archaeological and historical jewellery. In *Mineral Resources in a Sustainable World, Proceedings of the 13th Biennial SGA Meeting, Nancy, France, 24–27 August 2015*, Vol. 4, pp. 1301–1304.

Graf von Abensberg und Traun H., Ed. (1898) *Jahrbuch der Kunsthistorischen Sammlungen des allerhöchsten Kaiserhauses*, Vol. 19, Part II, F. Tempsky, Prague; F. Tempsky, Vienna; G. Freytag, Leipzig, 198 pp.

Graf zu Trauttmansdorff-Weinsberg F., Ed. (1889) *Jahrbuch der Kunsthistorischen Sammlungen des allerhöchsten Kaiserhauses*, Vol. 10, Verlag von Adolf Holzhausen, Vienna, 429 pp.

——— (1894) *Jahrbuch der Kunsthistorischen Sammlungen des allerhöchsten Kaiserhauses*, Vol. 15, Part II, F. Tempsky, Prague; F. Tempsky, Vienna; G. Freytag, Leipzig, 215 pp.

Grieb M.H., Ed. (2007a) *Nürnberger Künstlerlexikon*, Vol. 1. K.G. Saur Verlag, Munich, p. 234.

——— (2007b) *Nürnberger Künstlerlexikon*, Vol. 4. K.G. Saur Verlag, Munich, pp. 1806–1807.

Hampe T. (1904) *Nürnberger Ratsverlässe über Kunst und Künstler im Zeitalter der Spätgotik und Renaissance [Decisions of the Council of the Imperial City of Nuremberg]. II. Band 1571-1618*. Karl Graeser & Kie., Vienna; B.G. Teubner, Leipzig, 541 pp.

——— (1919) *Das Altnürnberger Kunstglas und seine Meister*. Verlag von Duncker & Humblot, Munich and Leipzig, pp. 36–41.

Hanus R., Hladký P., Vyskočilová G. (2022) Ulrike Sophie von Levetzow's jewels collection: Identification and restoration. *International Journal of Conservation Science*, Vol. 13, No. 2, pp. 367–380.

Kunckel J. (1689) *Ars vitraria experimentalis: Oder vollkommene Glasmacher-Kunst*. Verlegung Christoph Riegels, Frankfurt and Leipzig, pp. 275, 440.

Meyer-Heisig E. (1963) Caspar Lehmann. Ein Beitrag zur Frühgeschichte des deutschen Glasschnittes. *Anzeiger des Germanischen Nationalmuseums*, Vol. 1963, pp. 116–131.

Michel H. (1926) *Nachahmungen und Verfälschungen der Edelsteine und Perlen und ihre Erkennung*. Verlag von Ulr. Mosers Buchhandlung, Graz, pp. 18–19.

Museum Wolffianum (1714) Gottfried Rothen, Leipzig, p. 61.

Pfeiffer W. (1977) Vorwort. In S. Baumgärtner, *Gläser: Antike, Mittelalter, Neuere Zeit: Museum der Stadt Regensburg, Katalog der Glassammlung Sammlung Brauser*. Corona-Verlag, Karlsruhe, p. 5.

Pohlmann H. (1961) The inventor's right in early German law. *Journal of the Patent Office Society*, Vol. 43, No. 2, pp. 121–139.

Praktisches Handbuch für Künstler, aus dem Englischen nach der zwoten verbesserten und vermehrten Ausgabe übersetzt und mit Anmerkungen versehen [Practical Manual for Artists, Translated from English, Expanded and Revised] (1793) Zweyter Teil. Waltherische Hofbuchhandlung, Dresden, pp. 428–433.

Quast D., Schüssler U. (2000) Mineralogische Untersuchungen zur Herkunft der Granate merowingerzeitlicher Cloisonnéarbeiten. *Germania*, Vol. 78, pp. 75–96.

Rückert R. (1962) Gläser aus der Sammlung Dr. Brauser im Bayerischen Nationalmuseum. *Münchner Jahrbuch der bildenden Kunst*, Vol. 13, pp. 238–248.

——— (1982) *Die Glassammlung des Bayerischen Nationalmuseums München*. Vol. II. Hirmer Verlag, Munich, pp. 180–181.

Schmetzer K., Gilg H.A., Ranz H.-J. (2024) Das Granatrosensetzen - ein fast vergessenes Nürnberger Kunsthandwerk. *Gemmologie: Zeitschrift der Deutschen Gemmologischen Gesellschaft* (in print).

Stehlíková D. (2004) *The Bohemian Garnet*. Mucha Museum Ltd. in collaboration with the National Museum in Prague, p. 13.

Stern W.B., Gerber Y. (2004) Potassium-calcium glass: New data and experiments. *Archaeometry*, Vol. 46, No. 1, pp. 137–156, http://dx.doi.org/10.1111/j.1475-4754.2004.00149.x

Thieme U., Ed. (1913) *Allgemeines Lexikon der bildenden Künstler von der Antike bis zur Gegenwart*. Vol. 8. E.A. Seemann Verlag, Leipzig, p. 104.

Von Ursprung und Herkom[m]en samt Beschreibung aller Hand Wercker in der Stadt Nürnberg [Origin and Description of All Crafts in the City of Nuremberg] (ca. 1700) Germanic National Museum in Nuremberg collection. Signature: Merkel Hs 2° 981.

Von Ankunft und Herkommen aller Handwerker, so in der Stadt und Landwehr Nürnberg wohnhaft [Origin and Description of All Crafts in the City of Nuremberg] (1719) Historical Archive of the City of Nuremberg. Signature: B 12 Nr. 62.

Webster R. (1964) Composite stones. *Journal of Gemmology*, Vol. 9, No. 5, pp. 160–176.

Webster R., Anderson B.W. (1983) *Gems: Their Sources, Descriptions, and Identification*, 4th ed. Butterworths, London, pp. 460–462.

Wedepohl K.H. (2003) *Glas in Antike und Mittelalter: Geschichte eines Werkstoffs*. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, pp. 5–30.

Zboril R., Mashlan M., Barcova K., Walla J., Ferrow E., Martinec P. (2003) Thermal behaviour of pyrope at 1000 and 1100°C: mechanism of Fe^{2+} oxidation and decomposition model. *Physics and Chemistry of Minerals*, Vol. 30, No. 10, pp. 620–627, http://dx.doi.org/10.1007/s00269-003-0355-x

Żelasko S. (2014) *Barock und Rokoko im Hirschberger Tal: Stein- und Glasschnitt 1650-1780*. Glasmuseum Passau, pp. 11–12, 23, 112–113.