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Preliminary Results of Non-Destructive Investigations into the Enamels and Gemstones of the Preslav Treasure

The tenth-century Preslav Treasure illustrates the importance of the ancient capital of the First Bulgarian State, Veliki Preslav. Made of different metals and alloys, precious stones and various coloured enamels, it is one of the most significant archaeological discoveries of the Middle Ages in Bulgaria. Probably concealed during the Byzantine invasion in 971, it remained in the soil for ten centuries[1]. The treasure consists of Byzantine masterpieces of goldsmiths' works, such as a set of enamelled plaques, probably belonging to a diadem, a double-sided gold necklace with enamels and gemstones, enamelled earrings, and gold appliques.

In light of the fact that only a few Byzantine goldsmiths' works have been hitherto investigated with scientific methods, the analyses conducted in the frame of the research project are of great importance. Studying the Preslav Treasure was an interdisciplinary work, bringing together art historians, archaeologists, goldsmiths and scientists of the Leibniz-Zentrum für Archäologie (LEIZA, formerly RGZM), the Johannes Gutenberg University of Mainz (JGU) and the Justus Liebig University of Giessen (JLU), in co-operation with the Bulgarian Academy of Sciences and the Museum »Veliki Preslav«.

In this paper, we will present the initial results of the scientific analyses of gemstones, enamels and metals.

Analytical Methods

All analyses had to be conducted without taking samples, without manipulating the surface of the objects, and without placing them in a vacuum, in order to preserve their integrity. Our analytical strategy was thus to only use non-invasive and non-destructive techniques. First, Micro-X-ray Fluorescence analysis (μ-XRF) was used on non-prepared surfaces. Depending on the material and the condition of the surface, this provides elemental full or semi quantitative results. Parallel to μ-XRF, Raman spectroscopy was also employed. This yields structural phase information on pigments used in the enamel layers. Combining the results of these two techniques helped to determine enamel compositions, colouring agents and opacifiers, thus expanding our knowledge on Byzantine enamelling techniques and relationships to enamels of other areas.

The elemental analyses were performed using a μ-XRF Eagle III XXL (ROENALYTIC, Taunusstein) at the LEIZA in Mainz. With this device, quantitative, qualitative and semi-quantitative analysis of all elements with an atomic weight higher than that of neon can be achieved if the sample chamber is under vacuum, and beyond silicon under ambient conditions. The fragile condition of vitreous enamels, particularly, prevented us from performing analyses under vacuum, as low pressure might induce internal stress and result in the formation of cracks. As mentioned above, no preparation of the object surface was allowed, which reduced quantitative information gained from enamels in particular concerning the light elements, such as those containing silicon and sodium. Thus, the information we could collect regarding lighter elements contained in the enamel glass matrix was limited, while analysis of metallic materials was not constrained by this procedure.

The X-ray source was a rhodium anode with a maximum excitation voltage of 40 kV and an anode current of 1 mA. The beam diameter was 0.3 mm, which allowed the analysis of small areas, promising results with satisfactory spatial resolution. Two internal cameras (with different magnifications of 10× and 100×, respectively) recorded the beam in order to locate the analysed area precisely. The instrument was calibrated with glass standards from the Corning Museum of Glass, the National Institute of Standards (NBS) and various commercially available gold, silver and copper alloy reference materials. Light elements, such as sodium (Na), aluminium (Al) or magnesium (Mg), which are important for the characterisation of the enamel glass body could not be fully quantified as explained above. The numerical data presented here for vitreous materials were calculated to a total of 100 weight% by the elements that could actually be detected. Thus, the XRF results for glassy enamels are comparable to each other, but not to fully quantified results from other studies due to the limiting conditions of the analyses. The semi-quantitative character of these results nevertheless permits the acquisition of valuable information. The numerical

1 See the contribution by S. Bonev and P. Slavov in this volume.

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Fig. 1 Preslav Treasure. **a-b** Gold earring with pearls and gemstones. – (Photo S. Steidl, LEIZA). – Scale 1:1.

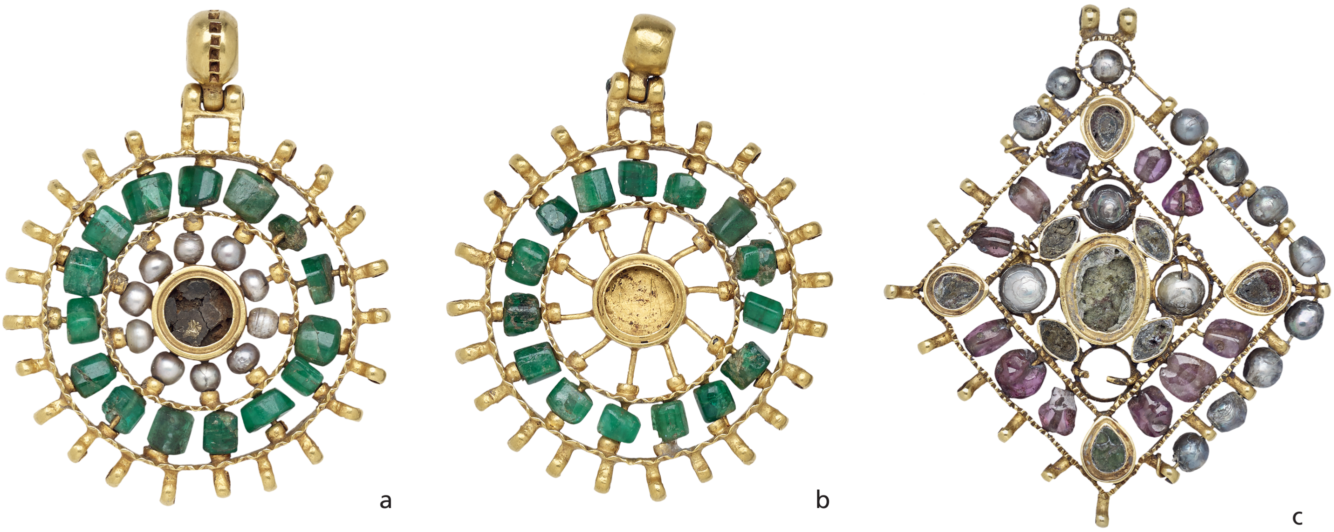

Fig. 2 Preslav Treasure. **a** Gold pendant with beryls (emeralds) and pearls – **b** Gold pendant with beryls (emeralds). – **c** Gold pendant with corundums and pearls – (Photos S. Steidl, LEIZA). – Scale 1:1.

values for metallic compounds were, however, not affected by these limitations.

The Raman analyses were performed using a LabRam HR800 spectrometer (Horiba Jobin Yvon) at the department of Geosciences at the JGU. Laser wavelengths of 532 nm and 488 nm with a 1800 lines/mm grating were used, which provided structural information revealing the general compositional type of vitreous enamels, and the nature of pigments and opacifiers. The spectral resolution is 0.5 cm^{-1}, which allowed good precision for peak positions. It was calibrated with a silicon chip at 520.7 cm^{-1}. The measurements were performed with 50× and 100× magnifying lenses, providing analysis diameters of a few micrometres in width. The laser power was modulated with density filters in order not to degrade the glass sample. Spectra interpretation for glass matrices was based on the comparison with standard compounds from the Corning Museum of Glass and the National Institute of Standards, with the RRUFF online database, the in-lab database of the Geosciences department of the JGU and references from the literature on ancient glass. The glass

Fig. 3 Preslav Treasure. Gold necklace with enamels, precious stones and pearls. – (Photo S. Steidl, LEIZA). – Not to scale.

types were therefore determined by comparing our Raman results to the classification of P. Colomban who used Raman spectroscopy as a new methodology to distinguish different types of glasses[2]. Glass types are related to the use of either silicon or lead as glass network formers and the choice of the fluxing agent (mineral soda, halophytic plant-ash soda, wood-ash or lead oxides).

Analysis of Gemstones

A pair of earrings (**fig. 1a-b**), three pendants (**fig. 2a-c**), the large enamelled necklace (**fig. 3**), a stone seal set in gold (**fig. 4a-b**) and a gold ring (**fig. 5**) are decorated with precious stones. Their colours are either translucent green or bear different shades of red (earrings, pendants and ring, **figs 1a-b. 2c. 5**), colourless with streaks of violet (necklace, **fig. 3**) and colourless (seal, **fig. 4a-b**). Raman analyses yielded the molecular structure of those stones and were completed by XRF analysis to specify the nature of the stones.

Green stones were used to manufacture the pair of earrings and two of the three pendants (**figs 1a-b. 2a-b**). Raman spectra revealed that the green gemstones are all beryls ($Be_3Al_2(SiO_3)_6$), belonging to the mineral variety called emerald. They are coloured green by trace amounts of chromium and vanadium. Beryls were also used as thin platelets in the almond-shaped settings on one of the pendants (**fig. 6**).

Fig. 4 Preslav Treasure. Rock crystal seal showing the Annunciation in gold setting: **a** Side. – **b** Front with intaglio. – (Photo S. Steidl, LEIZA). – Scale 2:1

Fig. 5 Preslav Treasure. Gold ring with carnelian intaglio. – (Photo S. Steidl, LEIZA). – Scale 2:1.

2 Colomban, Raman.

Fig. 6 Preslav Treasure. Detail of pendant with corundums and pearls in **fig. 2c**. – (Photo S. Steidl, LEIZA; labelling added by A. Bosselmann-Ruickbie). – Not to scale.

Fig. 8 Preslav Treasure. Detail of necklace with enamels, precious stones and pearls as in **fig. 3**: fluorite bead. – (Photo S. Steidl, LEIZA). – Not to scale.

Fig. 7 Preslav Treasure. Detail of pendant with corundums and pearls in **fig. 2c**. – (Photo S. Steidl, LEIZA; labelling added by A. Bosselmann-Ruickbie). – Not to scale.

Raman analysis helped to determine the mineralogical identity of the red gemstones. Two different minerals were identified: red corundum (Al_2O_3) and garnet (a family of silicate minerals with the general formula $X_3Z_2(SiO_4)_3$). On the pendant with reddish gemstones (**fig. 2c**), we identified mostly red corundum except for one stone, which is actually a garnet (**fig. 7, right**). The stone is fixed with a thin wire that was inexpertly wrapped around the pendant and thus differs from the method used for the other stones. Another gemstone (**fig. 7, left**) was also fixed in this way, but the analyses have confirmed that it is a red corundum like the other stones. It is not possible to determine if the repairs were executed in the Middle Ages or after the excavation (there is no documentation on restorations of the Preslav Treasure).

Other precious stones used in the Preslav Treasure are the rock crystal (SiO_2) seal in a gold setting (**fig. 4a-b**), the carnelian set in a ring bezel (**fig. 5**) and fluorite (CaF_2) on the large necklace (**fig. 8**)[3].

The pearls from the Preslav Treasure were also analysed; however, the results are limited due to the project's requirement to use non-destructive methods exclusively. This excluded the use of a vacuum, thus, we can only state that the pearls are natural, but no further information was gained as to their provenance.

3 The use of fluorite (CaF_2) in the Middle Ages is extremely rare, therefore, the stone could either be an exception to the rule or a later replacement.

Analysis of Metals and Alloys

The metallic parts of all the artefacts were analysed. The masterpieces of the treasure, such as the necklace, earrings and rings are made of high-carat gold alloys, while other objects are made of silver, bronze and brass. The choice of the metal and the composition of the alloys seem to be determined also by the expected mechanical use of each functional part. Surfaces were cleaned during the original restoration process after excavation so that the quantification should have been only marginally affected by corrosion.

The most impressive artefacts are the necklace (**fig. 3**), the three large pendants (**fig. 2a-c**) and five pairs of earrings (**figs 1. 9-12**). They were made from rich gold alloys with mostly more than 90 % gold. For the loops (example in **fig. 13**) that hold the weight of other pieces, the gold contents are lower. Pure gold is the most malleable metal, but by decreasing the amount of gold by adding silver and copper, the gold alloy becomes harder and thus stronger than pure gold and strengthens the mechanical property of the loop connecting different parts of the jewellery, such as a loop and its pendant. This testifies to the medieval goldsmiths' ability to control the production of alloys with precision.

Fig. 9 Preslav Treasure. Gold earring with enamels (details in **fig. 16**). – (Photo S. Steidl, LEIZA). – Scale 1:1.

Fig. 11 Preslav Treasure. Gold earring with pearls. – (Photo S. Steidl, LEIZA). – Scale 1:1.

Fig. 10 Preslav Treasure. Gold earring with enamels, missing its central enamel medallion. – (Photo S. Steidl, LEIZA). – Scale 1:1.

Fig. 12 Preslav Treasure. Gold earring with pearls. – (Photo S. Steidl, LEIZA). – Scale 1:1.

Fig. 13 Preslav Treasure. Detail of necklace with enamels, precious stones and pearls as in **fig. 3**: enamel with the Mother of God. – (Photo S. Steidl, LEIZA). – Not to scale.

Fig. 14 Preslav Treasure. Detail of gold suspension of rock crystal seal in **fig. 4a-b**. – (Photo M. Aubin).

Fig. 15 Preslav Treasure. Gold suspension ring, originally belonging to the rock crystal seal with gold setting in **figs 4a-b** and **14**. – (Photo M. Aubin; labelling by A. Bosselmann-Ruickbie). – Not to scale.

Analysing the gold composition also allows the detection of minor or major repairs on an artefact. The rock crystal seal (**fig. 4a, b**) is a good example: a repair was noticed on the gold setting of the crystal (**fig. 14**). The gold composition of the original structure and the repair are very different. Knowing the exact gold composition also helped to re-unite pieces from the same object that a thousand years underground have torn apart: a small gold loop found with the treasure (**fig. 15**) has the same gold composition as the rock crystal seal's setting. Moreover, its dimensions fit the hinge of the seal perfectly. We can assume that this tiny gold loop was originally the suspension loop of the pendant, as had been suggested by Kremena Stoeva, Museum Veliki Preslav.

Enamels Analysis

Green Enamels

Raman analysis revealed that the emerald green translucent enamels are made of soda glass (see **figs 3. 9-10. 13**) according to Colomban's classification[4]. We observed a high amount of potassium compared to other glasses. This can result from the use of plant ashes as a sodium source, which was not unusual for emerald green glass of the Roman period[5]. The green colour could be obtained from a copper-rich bronze as the glass contains tin and lead with traces of zinc[6]. All green enamels of the Preslav Treasure present a similar composition with slight differences probably due to the heterogeneity of the applied enamel powder or the use of different green glass batches for the preparation of the enamel.

Brown enamels

The shade varies from a brownish red to a dark purple translucent glass depending on the light and the thickness of the glass layer (**fig. 16** [detail of earring in **fig. 9** and on the book cover], beak and eye). These glasses are coloured brown by a high quantity of manganese combined with iron. The amount of potassium suggests that the type of glass matrix used from brown glasses is the same as the one used for green enamels. The Raman spectra reveal a soda-glass type with less potassium than green glasses, so the exact nature of the soda source (mineral or plant) could not be determined and a mixture of both is also possible.

4 Colomban, Raman 849.
5 Jackson/Cottam, Green Thought 141-143.
6 Biron, Emaux 134.

Fig. 16 Preslav Treasure. Detail of enamelled medallion with peacock, part of the gold earring in **fig. 9** (see also book cover). – (Photo M. Aubin).

Fig. 17 Preslav Treasure. Detail of enamelled gold earring in **fig. 10**, showing a running dog. – (Photo S. Steidl, LEIZA, labelling by A. Bosselmann-Ruickbie).

Fig. 18 Preslav Treasure. Detail of enamelled gold earring in **fig. 10** and **fig. 17** (other side), showing a peacock. – (Photo M. Aubin).

Fig. 19 Preslav Treasure. Detail of necklace with enamels, precious stones and pearls as in **fig. 3**: almond-shaped enamel pendant with bird. – (Photo M. Aubin).

Yellow enamels

There are two kinds of yellow enamels in the jewellery of the Preslav Treasure. The first one is a bright translucent yellow glass, and the second one is a light-yellow opaque glass. The translucent yellow glass, found on one of the earrings with the depiction of a dog (**fig. 17**) and a peacock on the other side (**fig. 18**)[7] is soda glass, characterised by low potassium contents (so-called natron glass), typical for the Roman period. The extremely low content of lead, antimony and tin gives a yellow colouration that is not based on the usual compounds we expect for yellow opacifiers. The high amounts of iron and manganese suggest that iron has been oxidised from Fe^{2+} (blue colour) to Fe^{3+} (yellow colour) by manganese ions Mn^{3+}. However, iron must also be partially trapped in another complex structure because the yellow hue is not too dark[8].

The opaque yellow glasses (**fig. 19**, wing) are typical lead-rich glass-pigment enamel composites known as early as Egyptian-period glass production. The Raman spectra of those enamels reveal the presence of quartz (SiO_2) as well as bindheimite ($Pb_2Sb_2O_7$), a yellow pigment. It is well known from the literature that lead antimonate pigments were used in the Roman period to produce yellow opaque glass. Normally, the substrate containing the yellow pigment was prepared beforehand and added to a natron glass[9].

7 For the full report, see the final publication on the Preslav Treasure (forthcoming).
8 Donald, High-iron 542-543.
9 Peake/Freestone, Tarbat Ness 104.

Fig. 20 Preslav Treasure. Detail of necklace with enamels, precious stones and pearls as in **fig. 3**: almond-shaped enamel pendant, detail of damaged area. – (Photo M. Aubin).

Fig. 21 Preslav Treasure. Enamelled gold medallion, fragment of pair for enamel earring in **fig. 10**. – (Photo M. Aubin).

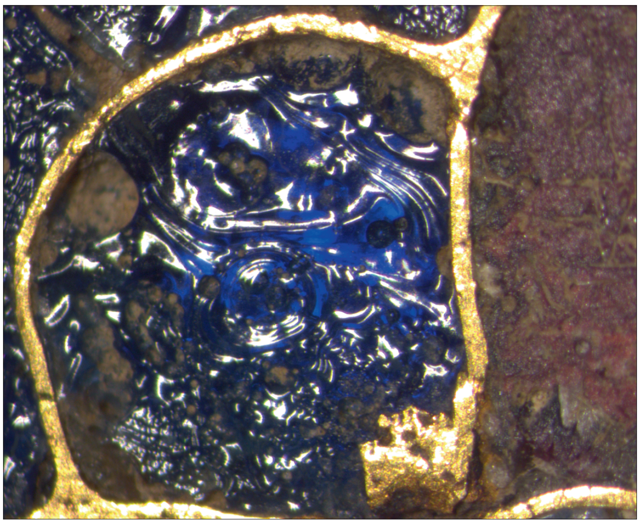

Fig. 22 Preslav Treasure. Detail of enamelled medallion in **fig. 21**. – (Photo M. Aubin).

White enamels

The white cells on face A of the necklace (**fig. 20**) show homogeneous quantification results with a high content of calcium and antimony. This correlates with the Raman results: we have found both calcium antimonates $CaSb_2O_6$ and $Ca_2Sb_2O_7$. These white compounds were used separately as a white pigment or combined with another pigment to modify the hue and the translucency. The same observation and results are obtained on face B but the quantification is more heterogeneous. It is interesting to note that the use of tin oxide SnO_2 could not be detected, although this pigment was already used in some western enamels and also glass beads at this time[10].

Blue enamels

Based on the compositional variations, we have distinguished three types of blue enamels on the two earrings (**figs 16-19. 21-22**). The first one is an opaque blue glass, which is lighter than the rest of the blue glasses. It is a soda glass from Colomban's Raman group 3, corresponding to natron-glass (very low potassium content)[11]. The colour is achieved by adding cobalt. To obtain this light opaque blue, the glass-maker used white calcium antimonate as an opacifier.

The second type of blue enamel is a translucent dark blue. The dark shade is due to a high amount of cobalt distributed in natron glass. The high amount of cobalt was possibly intended to convey a rather strong blue shade. If the translucent blue glass were too light, the yellowish gold substrate would shine through, which combined with the blue shade of the enamel, would probably produce a greenish mixed colour.

The last type of blue enamel is a dark blue natron glass that has a lower cobalt content. From the quantification results of silicium, cobalt, copper, zinc and lead, we distinguished what should be two different batches of this blue. The elemental compositions of these two batches are slightly different, but with probably the same original recipe, giving evidence that these blue enamels were made using two different sources or batches of blue glass powder.

Red enamels

There are three types of red enamel on the earrings (see **figs 13. 17-19**). Red enamels are only used for very small cells. The first type of red enamel is most frequently encountered: it is an opaque red lead glass with colour resulting from the presence of copper, most probably in the form of cuprite and elemental copper particles[12]. The high amount of lead

10 Ma et al., Glass Netherlands 107.
11 Colomban, Raman 849.
12 Bandiera et al., Red 2.

can serve two purposes: firstly, it helps to produce copper or cuprite, thus creating a shiny light red; and secondly, it decreases the melting point of the glass, making it technically easier to fill the enamels into the small cells[13]. The second type of red enamel is also a lead glass with a significant tin content, the red shade, a little bit darker than the previous one. The last type of red is made with an entirely different formula. The lead content is distinctly lower and the iron content higher.

Result of the Enamel Analyses

The Byzantine enamels in the Preslav Treasure are typical glass-based materials in the tradition of Roman glass technology with the use of soda glass for green, brown, and blue, lead glass for yellow and red, and calcium antimonate as white pigment. The recycling of Roman glass is a well-known practice in the early medieval and medieval periods for producing translucent or opaque glass for beads and enamelling[14]. *Tesserae*, vessel glass and window glass were re-melted or used as additives to existing glass melts. The recycling of Roman glass is a much more likely explanation than the possibility that a Byzantine enamelling workshop would still be in possession of original Roman glass recipes. However, even the re-use of pre-existing glass involves careful consideration of temperature and oxidation regimes when using it to melt the enamel glass onto an object.

Some questions remain regarding the manufacturing process of the translucent yellow glass containing a high amount of iron. To reproduce this type of enamel would allow a better understanding of the chemistry inside the glass matrix.

The large variety of colours and manufacturing techniques for enamels suggests that the craftsmen had a well-developed expertise. We were able to distinguish the glass nature, the colourants and the opacifiers they used and see the variations in the composition relative to the different batches. The results of the enamel analyses reveal a certain homogeneity in technique across the different objects. All the white opacifiers are calcium antimonates and none are tin oxides, all the blue, green and brown colours have a similar composition. The variations in the red glass compositions indicate an in-depth knowledge of producing glass with different melting points dedicated to different areas.

However, our results can only be compared to other studies by taking into account that the exact quantities of small elements could not be determined due to the fact that exclusively non-destructive methods had to be used.

Conclusion

The analyses of the Preslav Treasure have revealed a high mastery of the Byzantine craftsmen who executed the goldsmiths' works and re-melted and coloured the glass. They were able to control the exact quantities of metal components in order to give their artefacts specific properties. The high quality of gold and the use of precious stones, such as corundum, emeralds and garnets, supports the idea that the Preslav Treasure represents the Byzantines' finest techniques.

13 Welter, Characterisation 118-120.

14 Theophilus Presbyter transl. by Brepohl, Presbyter 152. 194.

Bibliography

Bandiera et al., Red: M. Bandiera / M. Verità / P. Lehuédé / M. Vilarigues, The Technology of Copper-Based Red Glass Sectilia from the 2nd Century AD Lucius Verus Villa in Rome. Minerals 2020, 10(10):875. DOI: 10.3390/min10100875.

Biron, Emaux: I. Biron, Emaux sur métal du IXe au XIXe siècle. Histoire, technique et matériaux (Dijon 2015).

Brepohl, Presbyter: Theophilus Presbyter, De Diversis Artibus, XXII, De Diversis Vitri Coloribus Non Translucidis, edited and commented translation by E. Brepohl. In: E. Brepohl, Theophilus Presbyter und das Mittelalterliche Kunsthandwerk 1, Malerei und Glas (Köln, Weimar, Wien 1999).

Colomban, Raman: P. Colomban / A. Tournié / L. Bellot-Gurlet, Raman Identification of Glassy Silicates Used in Ceramics, Glass and Jewellery: A Tentative Differentiation Guide. Journal of Raman Spectroscopy 37, 2006, 841-852.

Donald, High-iron: S. B. Donald / A. M. Swink / H. D. Schreiber, High-Iron Ferric Glass. Journal of Non-Crystalline Solids 352, 2006, 539-543.

Jackson / Cottam, Green Thought: C. M. Jackson / S. Cottam, »A Green Thought in a Green Shade«: Compositional and Typological Observations Concerning the Production of Emerald Green Glass Vessels in the 1st century A.D. Journal of Archaeological Science 61, 2015, 139-148.

Ma et al., Glass Netherlands: H. Ma / J. Henderson / Y. Sablerolles / S. Chenery / J. Evans, Early Medieval Glass Production in the Netherlands: A Chemical and Isotopic Investigation. Nederlandse archeologische rapporten 81 (Amersfoort 2023).

Peake / Freestone, Tarbat Ness: J. R. N. Peake / I. C. Freestone, Analysis of the Glass and Glass-Working Waste. In: M. Carver / J. Garner-Lahire / C. Spall (eds), Portmahomack on Tarbat Ness: Changing Ideologies in North-East Scotland, Sixth to Sixteenth Century AD (Edinburgh 2016) D102-D106.

Welter, Characterisation: N. Welter / U. Schüssler / W. Kiefer, Characterisation of Inorganic Pigments in Ancient Glass Beads by Means of Raman Microspectroscopy, Microprobe Analysis and X-Ray Diffractometry. Journal of Raman Spectroscopy 38, 2007, 113-121.

Summary / Zusammenfassung / Résumé

Preliminary Results of Non-Destructive Investigations into the Enamels and Gemstones of the Preslav Treasure

The Preslav Treasure serves as a testament to the prominence of the ancient Bulgarian capital, Veliki Preslav. Comprised of richly decorated gold and silver artefacts, it represents one of the most significant archaeological discoveries related to the Byzantine period in Bulgaria. Likely concealed during the Byzantine invasion of 971, the treasure remained undisturbed in the soil for a millennium. The collection consists of exquisite goldsmithing masterpieces, featuring precious stones, pearls and enamelled decorations. With its *terminus ante quem*, the artefacts in the treasure are among the rare examples of dated Byzantine enamels and goldsmiths' works with a documented provenance.

The analysis of this Bulgarian national treasure necessitated non-invasive methods to preserve the integrity of these precious and fragile objects. Our analytical approach involved the integration of non-destructive techniques, such as micro-X-ray fluorescence (μ-XRF) and Raman spectroscopy, to elucidate the manufacturing processes, as well as to analyse the composition of the metals, especially gold, gemstones, and enamels. These methods provide elemental and structural information that is crucial for understanding the materials and techniques used.

The analysis of the Preslav Treasure has revealed that the Byzantine enamels present on these artefacts are typical of glass produced within the Roman glassmaking tradition. The composition of the gold indicates a sophisticated capability to create specific alloys tailored to the intended function of each gold component. This research has significantly enhanced our understanding of Byzantine technology and materials, as well as the skills of the craftsmen who excelled in producing such magnificent works of art.

Vorläufige Ergebnisse der zerstörungsfreien Untersuchung von Emails und Edelsteinen im Preslav-Schatz

Der Preslav-Schatz zeugt von der Bedeutung der alten bulgarischen Hauptstadt Veliki Preslav. Er besteht aus reich verzierten Gold- und Silberobjekten und stellt eine der bedeutendsten archäologischen Entdeckungen Bulgariens aus der byzantinischen Zeit dar. Wahrscheinlich wurde der Schatz während der byzantinischen Invasion im Jahr 971 versteckt und blieb ein Jahrtausend lang ungestört im Boden verborgen. Der Schatzfund besteht aus höchst qualitätvollen Goldschmiedearbeiten, die mit Edelsteinen, Perlen und Emails verziert sind. Mit ihrem *terminus ante quem* gehören die Artefakte des Schatzes zu den seltenen Beispielen datierter byzantinischer Emails und Goldschmiedearbeiten mit dokumentierter Provenienz.

Die Analyse dieses bulgarischen Nationalschatzes erforderte nicht-invasive Methoden, um die Unversehrtheit dieser kostbaren und zerbrechlichen Objekte zu bewahren. Unser analytischer Ansatz umfasste die Integration zerstörungsfreier Techniken wie die Mikro-Röntgenfluoreszenz (µ-XRF) und die Raman-Spektroskopie, um die Herstellungsprozesse aufzuklären und die Zusammensetzung der Metalle, insbesondere des Goldes, der Edelsteine und der Emails zu analysieren. Diese Methoden liefern chemische und strukturelle Informationen, die für das Verständnis der verwendeten Materialien und Techniken entscheidend sind.

Die Analyse des Preslav-Schatzes hat gezeigt, dass die byzantinischen Emails auf diesen Artefakten typisch für Gläser sind, die in der Tradition römischer Gläser stehen. Die Zusammensetzung des Goldes deutet auf eine hochentwickelte Fähigkeit zur Herstellung spezifischer Metall-Legierungen hin, die auf die beabsichtigte Funktion der einzelnen Goldelemente zugeschnitten waren. Diese Forschungen haben unsere Kenntnisse der byzantinischen Technologie und Materialien sowie der Fähigkeiten der Handwerker, die sich bei der Herstellung solch großartiger Kunstwerke auszeichneten, stark erweitert.

Résultats préliminaires des examens non destructifs des émaux et des pierres précieuses du trésor de Preslav

Le trésor de Preslav témoigne de l’importance de l’ancienne capitale bulgare, Veliki Preslav. Composé d’objets en or et en argent richement décorés, il représente l’une des plus importantes découvertes archéologiques liées à la période byzantine en Bulgarie. Probablement dissimulé lors de l’invasion byzantine de 971, le trésor est resté intact dans le sol pendant un millénaire. La collection se compose de chefs-d’œuvre d’orfèvrerie, avec des pierres précieuses, des perles et des décorations émaillées. Par leur *terminus ante quem*, les objets du trésor comptent parmi les rares exemples d’émaux et de pièces d’orfèvrerie byzantins datés dont la provenance est documentée.

L’analyse de ce trésor national bulgare a nécessité des méthodes non invasives pour préserver l’intégrité de ces objets précieux et fragiles. Notre approche analytique s’est fondée sur des techniques non destructives, telles que la fluorescence micro-X (µ-XRF) et la spectroscopie Raman, afin d’élucider les processus de fabrication et d’analyser la composition des métaux, en particulier de l’or, des pierres précieuses et des émaux. Ces méthodes fournissent des informations élémentaires et structurelles qui sont cruciales pour comprendre les matériaux et les techniques utilisés.

L’analyse du trésor de Preslav a révélé que les émaux byzantins présents sur ces objets sont typiques des verres produits dans la tradition verrière romaine. La composition de l’or indique une capacité sophistiquée à créer des alliages spécifiques adaptés à la fonction prévue de chaque composant en or. Ces recherches ont considérablement amélioré notre compréhension de la technologie et des matériaux byzantins, ainsi que des compétences des artisans qui ont excellé dans la production de ces magnifiques œuvres d’art.