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Russian Icons, 17th–18th c. Non-Destructive, Non-Invasive Diagnostic Methodology for an Integrated Study of Micrographic Triptychs from the Benaki Museum Collection

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Abstract: The study aims to enhance our knowledge of the materials and techniques applied in the making of Russian, portable ecclesiastical paintings produced after the 16th century, and to evaluate a pilot, non-destructive, non-invasive, research methodology proposed for their examination. Based on research relating to the historical background of their production and distribution in the South, the availability of materials and the applied techniques, a non-destructive, non-invasive methodology is exploited to examine three triptychs and two polyptych side panels belonging to the collection of the Benaki Museum. As their small size and excellent state of preservation prohibit sampling, a study scheme based on visual examination, the implementation of a series of spectral imaging techniques (VIS, IRRFC, SWIR, UVL, RTI, X ray) and a non-invasive micro XRF analysis is tested. Fiber and wood-type identification are carried out microscopically. The collected information relates to the making of the frames and the supports, the design, the use of metal foils and pigments, the order of application of paint layers and the rendering techniques. Due to the non-destructive, non-invasive character of the procedure, organic constituents are not thoroughly examined. Use of an expected palette was confirmed, but the modelling proved rather sophisticated. Among the most interesting finds were the use of distinct pigment mixtures for the underpaints of the flesh parts and certain deviations from the expected rendering techniques. The methodology proved very effective in terms of its output, the global approach of the construction technique, the user-friendly application, the low cost and time consumption factors.

Keywords: technical examination; Russian icons; non-destructive; non-invasive; imaging; XRF spectrometry; pigments

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1. Introduction

When technically compared to icons produced in other regions, despite obvious structural similarities, panels from Russia are differentiated due to techniques applied for the rendering of specific areas, particular materials used and the type of interventions they have undergone over the course of time [1] (p. 90). For conservators and art historians, optimization of the handling of such collections raises a series of questions relating to technique, and also provides insights into the artists' working methods.

Written sources on the purchase of materials and the assignment of specific works—such as, the oldest (16th-century), preserved in Novgorod, Russian iconographic model with instructions for artists, and loose sheets and book pages with information for hagiographers dating from the 17th century [2] (p. 36)—include some information on pigments and iconography. However, as even mid-19th century publications of excerpts from iconographic anthologies—such as the *Typikon* of Bishop Nektarios (1599), the 17th-century text of Nicodemus of *Siysk*, and the *Stroganov*, *Bolshakov* and *Gourianov* anthologies [3] (p. 35), [4] (p. 40)—referring to materials and painting methods contain no interpretations, correlation to modern materials and terminology remain an issue. The first attempt to correlate pigments mentioned in Russian archival sources to chemical compounds or minerals as they are known today was carried out by V. A. Shchavinsky, using optical means while pigment analysis, as conceived today, was first presented by F. F. Filatov [3] (pp. 34–38, 41). Informative studies comprehensively recording methods and materials used in Russian painting exist in the form of textbooks [5,6] and modern manuals on iconography [4], shedding light on issues relating to terminology, technique, and materials. On the construction of old Russian icons and pigment use, relevant publications by the State Tretyakov Gallery [7,8] and the GosNIIR online library (http://www.gosniir.ru/library/conferences/conservation-researches-2.aspx (accessed on 26 December 2022)) are invaluable sources. Nevertheless, data on panels from the 16th century onwards remain scarce [9–13] and overall insufficient to adequately support the design of conservation treatments.

The paper is based on the MSc. thesis of A.E. Kalliga [14], carried out in support of the conservation treatment of the Benaki Museum collection of Russian ecclesiastical art, performed within the context of the ERC funded, RICONTRANS project (https://ricontrans-project.eu (accessed on 19 October 2022)). It presents the technical examination of a group of micrographic triptychs (inv. nos. 14126, 14147, 14461, 29534, 29535), dating from the 17th to the first half of the 18th century [15] (pp. 115–120) (Figures 1–4). A non-invasive, non-destructive approach is proposed and evaluated, aiming to add knowledge on materials and techniques applied in the making of Russian icons produced after the 16th century, which is considered a milestone for Russian icon painting due to the broadening of the cultural horizon of the kingdom caused by the significant territorial expansion of the state under the rule of Ivan III the Great (1462–1505) and the development of new trade routes [16] (p. 21), [17] (pp. 40–41). To optimize the evaluation of the workflow, works both cleaned and covered by heavily tarnished varnish coatings are examined.

Figure 1. Triptych with the Hospitality of Abraham, the Last Supper, the Wedding in Cana and the Twelve Great Feasts, late 17th–early 18th century, 13.5 × 24.7 × 2 cm, (inv. no. 14126), Athens, Benaki Museum. © Benaki Museum, Athens.

Figure 2. Triptych with the Presentation of the Virgin, the Annunciation, the Nativity, the Twelve Feasts and other scenes, 17th century, Stroganov workshops, 26 × 45 × 2.5 cm, (inv. no. 14147), Athens, Benaki Museum. © Benaki Museum, Athens.

Figure 3. Two wings of a triptych with the Virgin Blachernitissa and Saints Demitrios and George, first half of the 18th century, 14.5 × 18 × 2 cm, (inv. no. 14461), Athens, Benaki Museum. © Benaki Museum, Athens.

These delicate objects of private reverence and high artistic quality stand among the oldest examples of Russian ecclesiastical paintings in the collection. Also known as "triptychs for the journey", they were usually produced on commission for distinguished members of society to be used as portable iconostasis during travel or war. Typically decorated with autonomous micrographic scenes arranged in rows, they were made on thin panels, occasionally ending in flame-shaped arches which were characteristic of Russian art [18] (p. 40). Their technology is considered identical to that of Russian icons of the time. Painted wings were framed with metal lamina joined with hinges, to allow secure closure while external surfaces could be reinforced with solid or perforated metal decorative plates.

(a) (b)

Figure 4. Side panels of a polyptych with two-tier portraits of saints, second half of the 17th century, (**a**): 33.6 × 20.9 × 2.4 cm, (inv. no. 29534), (**b**): 33 × 20.5 × 2.4 cm, (inv. no. 29535), Athens, Benaki Museum. © Benaki Museum, Athens.

Criteria Relating to the Methodology and the Choice of Analysed Spots

The proposed methodology was dictated by the miniature size and excellent preservation of the paintings, the type and variety of sought information and the availability of means. Non-invasive techniques capable of ensuring a systematic recording of reliable technical information from all layers of the composite constructions were selected, also with the goal of collecting data relating to pathology. Accessibility to facilities and equipment, factors relating to cost and time consumption, and experience in the implementation of techniques and interpretation of the results were also considered, since the design and evaluation of a very simple but efficient and reliable workflow to be further implemented for the study of the collection was among the research requirements.

Visual examination and imaging under magnification (0.6–200X) were carried out to collect information on construction, the adopted painting methods, and the pigment mixtures. These were followed by the implementation of an array of spectral imaging techniques (VIS, RTI, UVL, IRRFC, SWIR, X ray) chosen to gradually input data from all levels of the strata, prevailing over the use of multispectral (MSI) due to the higher resolution of the resulting images and the recording of infrared reflectance (IRR) from a greater depth. The well-established techniques were, in the context of this study, applied upon the following rationale. X-ray imaging was used to collect information relevant to the supports: the wood grain orientation, the presence of flaws and/or reinforcements, the use of canvas and the mounting of the panels onto the metal frames, but also to support pigment characterization with data relating to the absorbance ratio of each chromatic region. RTI was performed to obtain a detailed record of the painting's relief, inform on the use of an incised design, the relative thickness of the paint films, the brushwork, cracking patterns and surface damages. SWIR imaging was implemented to document the drawn design and pentimenti, and UVL to detect overpaintings and record the distribution of organic materials on the surface. With the exception of RTI, all imaging results were exploited, using images of pigment reference tables [19] captured under the same conditions and relevant published data [20], to provide an estimation of the pigments and colourants used and to optimize the selection of areas to be further analysed. A strict protocol was followed throughout the capturing sessions to ensure alongside repeatability, the compatibility of the results.

Identification of the wood type was attempted without sampling, as most boards were radially cut, displaying on each seat characteristics that would show in respective thin sections of a sample [21] (p. 18). The method had procured good results in the case of Greek icons from Kastoria [22] (pp. 84–85) but also for Russian panels [6] (p. 25). Specific characteristics were observed within the growth rings along the lower edge of the panels, and further exploited using identification keys [23] (pp. 44–46). Fabric types were identified microscopically through observation of fibre morphology and comparison to reference samples [24].

Scanning micro-XRF analysis was used for the qualitative identification of inorganic components in a supplementary way, aiding pigment identification and investigation of the techniques applied in the rendering of specific areas by recording differentiations in the composition of overlapping paint mixtures. Observations confirming that as a rule, the rendering followed the byzantine tradition, exploiting successively lighter tones laid over darker passages, and that in most areas corresponding to garments, each tone had been produced by addition of white to the one previously applied, formed the base of choice for areas to be analysed (approx. 20 per object). The accurate distinction of chromatic regions was also a determining factor, as certain areas differing in tone but not in hue in the visible spectrum were differentiated under other imaging conditions, indicating the use of distinct pigment mixtures. Shaded and highlighted areas were added to the main body of selected regions to aid in the identification of pigments utilized for tone differentiations in the multi-layered strata. Line scans, providing analysis at regular intervals of known pacing, were also performed along selected axes to record the rendering of flesh areas more accurately. Selected paths traversed areas of successive strata complexity, from single underpaints to the most complex stratigraphy, including mid-tones, highlights, shadowed areas and where possible, the warm-coloured passages applied as blush. Targeting was limited to central areas, as the approach of the spectroscope to the edges of the panels was obstructed by the metal framings.

2. Materials and Methods

2.1. Visual Examination

Visual examination was carried out using an Olympus SZX9 stereoscope mounted with a Highlight 3100 halogen light source for magnifications ranging from 0.6X to 150X, and with a PROVIS AX70 polarizing microscope with UP-S halogen light source from the same manufacturer, for magnifications ranging between 50X and 200X.

2.2. Imaging

For VIS, IRR and UVL imaging, simple means were exploited. Nikon SLR digital cameras and lenses with tungsten or UVA (315–400 nm) dual light setups were positioned at approximately 45° with respect to the focal axis of the camera, with B&W #93 and Kodak Wratten # 3 filters. IRRFC images were procured from VIS and IRR (https://chsopensource.org/infrared-false-color-photography-irfc (accessed on 5 March 2019)).

Higher-quality IRR imaging was achieved using a New Imaging Technologies (niT) digital infrared WiDy-SWIR camera, with InGaAs sensor (900–1700 nm). To fully exploit the analytical capacity of the camera, the distance from the objects was limited to the minimum possible. and the collected images were photo merged.

For macro and micro imaging, a CCD Olympus ColorView camera was used, mounted either on the SZX9 stereoscope or the PROVIS AX70 polarizing microscope and light sources as described above. Images were acquired using the analySIS docu v5.0 software developed by Olympus Soft Imaging Solutions.

Highlight RTI [25] (p. 186) was carried out [26] separately on each wing to optimize results by eliminating shadowing due to the frames. Images were generated and viewed with the RTI Builder Ver. 2.0.2 and RTI Viewer Ver. 1.1. software (freely available through: https://culturalheritageimaging.org).

A General Medical Merate SpA, CPI-CMP 200 apparatus and a Fujifilm FCR Capsula X digitizer were used for X-ray imaging. The imaging plates were positioned beneath the panels which faced upwards, and the X-ray tube was positioned exactly above them at a height of approximately 1,5 m. No additional filtration was used.

Wood identification, fibre observation and imaging were carried out with a Dino-Lite Edge portable digital polarizing microscope, an Olympus PROVIS AX70 optical polarizing microscope with ColorView CCD camera and the analySYS docu software.

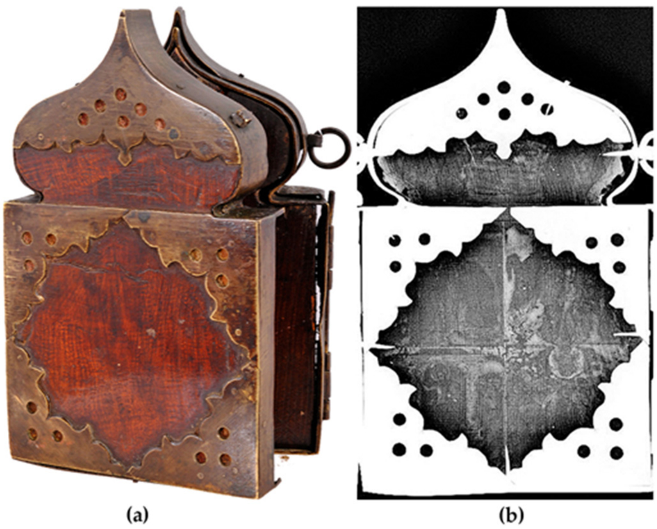
2.3. XRF Analysis

The device used for XRF analysis is an adaptation of a commercial Artax (Bruker Nano) micro-XRF spectrometer [27,28]. The analytical capacity of the setup ranges between 31–76 µm for X-rays whose energy, respectively varies between 22 and 4.5 keV, allowing the analysis of all elements of the periodic table, from silicon to uranium. Depending on the element and the type of sample analysed, the minimum detection limits ranged from 10 to 1000 µg/g for measurement times of 15–20 min. A Ni, 25.00 µm filter was used for point analysis, with energy set to 50 KeV and measurement time 100 s. Spectra were processed via the Bruker Artax V49 software.

3. Results and Discussion

3.1. Metal Frames

The metal frames (Figure 5) are made in a uniform manner. Visual examination showed that for each wing, a single lamina (0.5–1 mm) was used, bent and curved into the desired shape and joined in a lower inner corner. The width of the lamina is reduced along a side of each outer wing to make space for the one that is inward folding. Panels are held in place with metal pins, which are recorded well by X-ray imaging (Figure 5b), passing through pre-bored holes. Depending on size, one or two are placed on each side and at least four along the arches. Wings are joined with metal rods bearing spherical decorative endings, and suspension rings are usually attached at the most prominent points of the central wing's arch. Perforated brass sheets, pinned onto the external surfaces over brightly coloured fabrics, add strength to the constructions. XRF analysis confirmed that brass of high purity was used in the #14126 triptych. In addition to copper and zinc, iron was identified in the other two triptychs, lead in #14461, and nickel in #14147.



(a) (b)

Figure 5. Triptych, inv. no. 14126, (**a**) external view, (**b**) X-ray imaging of the central wing. © Benaki Museum Conservation Department.

3.2. The Panels

Care and attention are displayed in the selection of the panels, which are made of single boards, usually radially cut, and orientated with vertical grain direction to ensure maximum mechanical strength and minimum distortions over time. Only in the case of the polyptych side panels has a poor selection of boards, which include part of the trunk centre, led to mild warping.

In the two smaller triptychs, the lack of a *kovcheg*, a recessed level defining the position of the scene, could relate to size; whereas, on the much larger polyptych wings, a double *kovcheg* was carved. Such features are considered typical of Russian icons' but seem to have been used more sparingly from the second half of the 17th century [4] (p. 17).

X-ray imaging of the wings (Figure 6c) showed that pegs, protruding along both lateral seats of each panel, correspond to beams inserted in parallel direction to the surface of the paintings, intersecting at about the middle of their width. As no reference was found relating to a constructional use of this type of internal reinforcements, it is estimated that they belong to a latter intervention aiming to stabilize the warping panels. The identical treatment supports both common origin and parallel course in time, while the use of birch wood (*Betula* spp.) for the beams, thriving in the plains of Russia but in Greece, found only in Rhodope, could indicate the geographical area wherein this operation was performed.

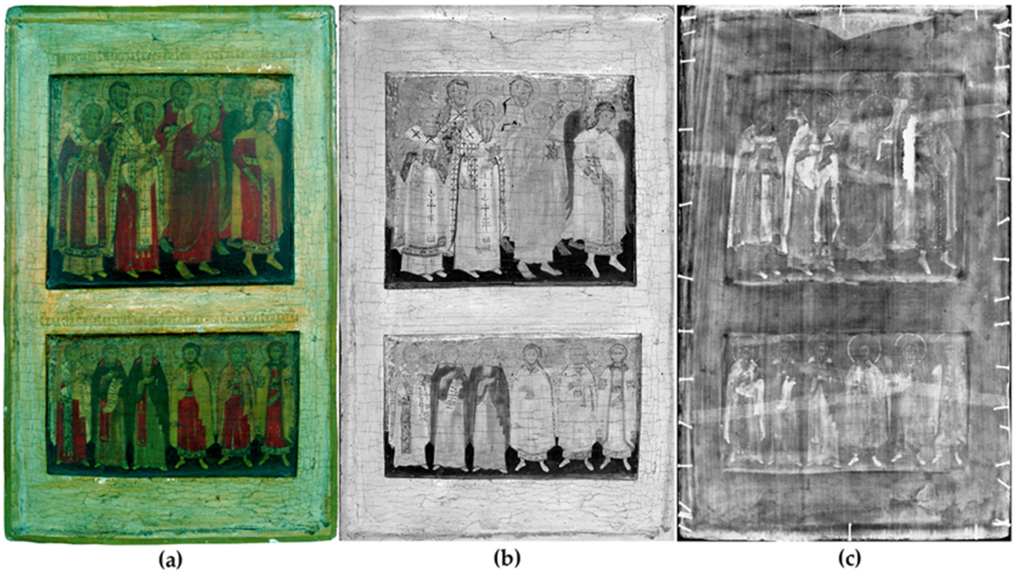


Figure 6. Polyptych side panel, inv. no. 29534, (**a**) IRRFC, (**b**) IRR and (**c**) X-ray imaging. © Benaki Museum Conservation Department.

The anatomical characteristics of cypress wood (*Cupressus Sempervirens* L.) were identified in the #14126, 29,534 and 29,535 panels; and it is a most probable match for the #14147. Although this, well known for its exceptional natural properties and inherent strength [29] species, was extensively used in the making of panels around the Mediterranean, it was hard to find in Russia, where it is not native. Among the species of wood identified in Russian icons, only one reference to cypress was found [6] (p. 25), [13] (p. 63), [30] (p. 706), as it was a product of import that began being used after the 16th century, when trade relations with Europe developed [5] (pp. 13–14). Its use can therefore be considered consistent with the dating of the works while the selection of this type supports the luxurious character and elaborate construction of the objects.

3.3. The Canvas

The panels are covered by fine canvas of a plain tabby weave, either of flax (*Linum usitatissimum* L.) or cannabis (*Cannabis sativa* L.). Fibres are smooth, of steady width, bearing characteristic transverse, diagonal and often X-shaped flares [31] (pp. 16, 18). Further distinction is not possible with the applied methodology, and both species thrive in Russia; however, the use of linen is more frequently mentioned in the making of Russian icons. The canvas, showing under close observation, was placed over the boards in a neat orientation. X-ray imaging (Figure 5b) proved full coverage of the panels of the triptychs but, due to the thickness and the composition of the overlying layers abd the strong recording of the wood grain, it procured no information on the polyptych side wings (Figure 6c). Nevertheless, the differentiation of the ground cracking patterns recorded in IRR images between surfaces corresponding to *polya* and *kovcheg*, (Figure 6b) could relate to an uneven distribution of canvas on the surface of these panels. A partial panel coverage has also been reported in a group of five icons from northern Russia, dating from between the end of the 16th and the early 17th century [12] (p. 758).

The warm-coloured fabrics placed under the exterior metal decorations are made of silk (*Bombyx mori*). The fibres are smooth, constant in width and, besides their double spiked ends, lack particular characteristics [31] (p. 137). In the #14126 triptych, the width of the warp and the weft fibres differ, and their colour variation (bright brown vs. deep red) indicates that the yarns had been dyed prior to weaving.

The remains of a red fabric found under pin heads fixed along the sides of the polyptych wings were made of cotton (*Gossypium*). The flattened, round-edged, ribbon shaped fibres of uneven thickness present distinct reversal zones and appear bright under all crystallographic orientations of the specimen [31] (pp. 14, 137), [32] (pp. 27, 29).

3.4. Design

A variety of approaches are recorded which relate to the handling of the design: exclusive use of incisions in triptych #14461, an extensive drawing in #14126 and the coexistence of both types in #14147 and the polyptych wings.

Single, fine, shallow incisions outlining the garments, flesh areas and halos are clearly recorded by visual examination, macro and RTI imaging in #14461, but no evidence is found of a drawing.

In #14126, the underdrawing is detected visually (Figure 7b) and by IRR imaging (Figure 7d) in all areas but those corresponding to flesh, procuring exceptionally high absorptions. The steady in width brushstrokes, made with a dark liquid paint and a fine brush, are clearly discerned in areas further rendered with transparent or semi-transparent paint mixtures, such as the purples and the whites, respectively. The design is utilized here as a means of describing important elements of the composition that are further processed only sparingly and, in this respect, it decisively contributes to the result. This technique is consistent with traditions followed by Russian icon painters after the 16th century, who exploited their drawings beneath undergrounds of escalating transparencies [33] (p. 34).

Two inscriptions, located along the lower edge of the central wing (Figure 8), although initially attributed to a signature or date, proved to be related to the construction process, indicating the scene to be depicted in the space above. The initial estimation was rejected, as Russian hagiographers rarely signed their works, [34] (p. 81, 85), [35] (pp. 25, 31–33), and because the inscription under the scene of the Palpation of Thomas reads “ΘΟΜИΗ” (Thomas). Rough notes of this type, and draft sketches, although usually deleted when no longer useful, have also been recorded in other icons, such as the “Tree of the Moscow State (praise of Our Lady of Vladimir)” (State Tretyakov Gallery, inv. no. 28598) by Simon Ushakov [11] (pp. 53–55), and the “Dormition of the Mother of God”, depicted on the reverse of the icon of the Virgin of Don [7] (p. 26).

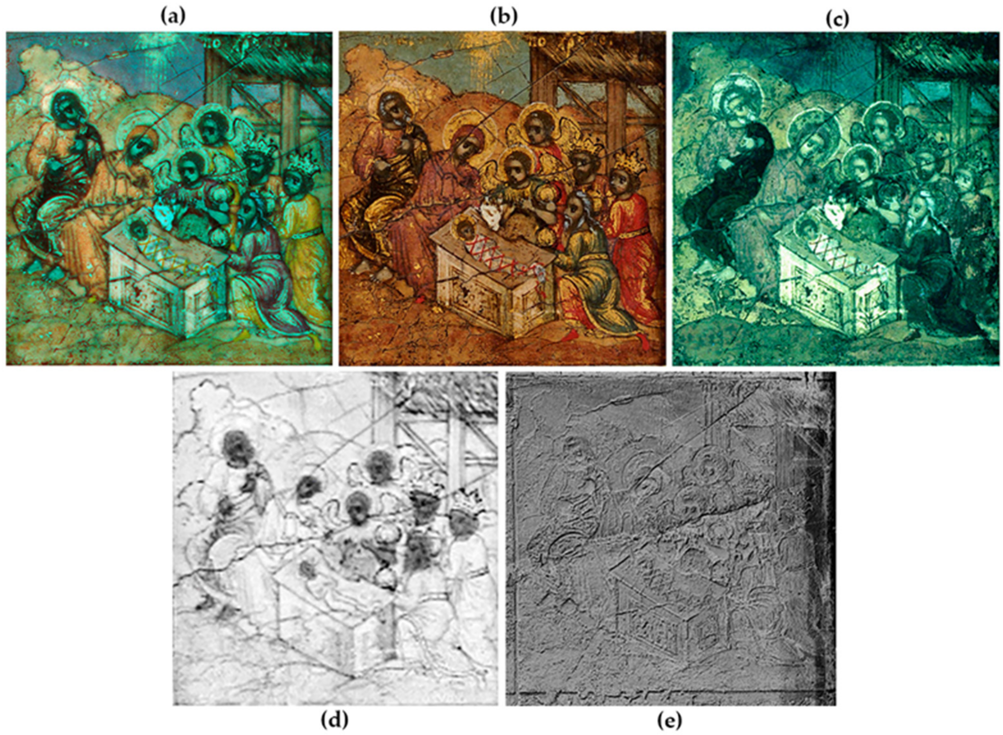


Figure 7. The Nativity scene (inv. no. 14126) under different imaging conditions: (**a**) Infrared-reflected false colour (IRRFC), (**b**) Visible (VIS), (**c**) UV-induced visible luminescence (UVL), (**d**) Infrared-reflected (IRR), (**e**) Reflectance transformation imaging (RTI), (actual size 3.5 × 3.5 cm). © Benaki Museum Conservation Department.

Figure 8. Triptych, inv. no. 14126, detail of the central wing; visible (VIS) with infrared-reflected (IRR) overlays demonstrating the design and two inscriptions along the lower margin relating to the construction process. © Benaki Museum Conservation Department.

In the #14147 triptych, the boundaries of the scenes and the positioning of inscriptions are marked with incisions made using a ruler and various tools, resulting in markings that vary in form; they are wide and deep to demarcate each scene, but narrow, shallow and in parallel pairs for the inscriptions. Curved incisions of a similar form, executed in freehand, are used to define areas to be gilded, some outlines of the composition and the halos (Figure 9a). Visible where left uncovered by paint, they also show well in RTI.

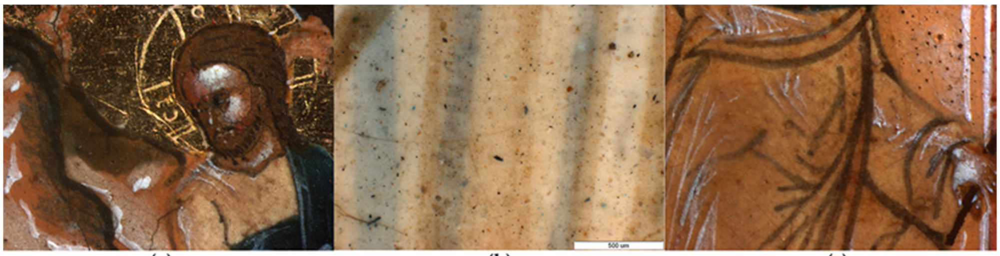


Figure 9. Triptych inv. no. 14147. Micro imaging (**a**) freehand incisions and dark lines of the drawing, showing through (**a**,**c**) transparent and (**b**) semi-transparent underpaints. © Benaki Museum Conservation Department.

An extensive underdrawing, executed with thin, confident touches of steady width and some dark dilute paint, often stagnating at end of the lines, is fully recorded in IRR images (Figure 10b). Used to describe each scene in detail, but also for facial features and details of the flesh, it often deviates from the incised markings, but is again systematically exploited under colour passages of medium or high transparency (Figure 9b,c and Figure 10a). This technique, apparently widely used after the 16th century, has also been recorded in other panels produced by the *Stroganov* workshops [2] (p. 114).

Figure 10. Triptych inv. no. 14147. Left wing, (**a**) VIS, (**b**) IRR, (**c**) IRRFC (**d**) UVL imaging. © Benaki Museum Conservation Department.

The underdrawing is not always slavishly followed. Some elements of the composition are modified when colour passages are applied, and others are omitted. Characteristic examples can be observed in some of the scenes of the left wing (Figure 10a,b). In the Baptism, the final shape of the waves was found to deviate from that of the underdrawing and in the Lamentation, a ladder—revealed by IRR imaging—was omitted when the colour passages were applied.

Although no safe conclusions can be drawn relating to the order of execution of the two types of design, their distinct role is clear. The comfortable, relaxed style of the freehand and the often fragmentary, fine incisions found in the interior of individual scenes but not faithfully followed with colour indicate an auxiliary role in contrast to the detailed underdrawing which, although occasionally modified with colour, is as a rule followed and systematically exploited for the modelling of draperies and other elements of the compositions.

The two types of design coexist in the polyptych side panels. Concise and somewhat sketchy incisions are mainly used to define the boundaries of areas to be covered with metal leaf. The faint, narrow, and of constant width lines of the underdrawing bear no traces of the use of liquid paint. They are used to demarcate the main folds of the draperies, the position and characteristics of the faces and areas designated for the rendering of the hands and the feet.

3.5. Use of Metal Leaves and Striations

Gold was used extensively, applied either in the form of burnished leaves, placed over a warm coloured, iron-containing substrate, or as emulsions, following the shell gold technique. Burnished gold leaves are used in the background, for the halos and for garments where they are often further embellished with coloured transparent coatings (glazes) or paints. Gold striations are used to highlight garments, in the scenery and for inscriptions. The gold leaves were found to be of high purity, except for #14461, where traces of silver were also detected.

In #14147, silver is also used for the rendering of building details and garments. Leaves are burnished directly onto the ground and further decorated with fine black lines or coloured glazings. A silver emulsion is used to decorate glories and medals.

Although the backgrounds of the polyptych wings macroscopically seem gilded, use of silver leaf affixed over a layer of iron oxides was confirmed by XRF analysis.

The adhesion of the gold leaf on the ground of old Russian icons, as described in literary sources, was carried out over a thin layer of ochre and animal glue or garlic juice, and alternatively, on a thicker coloured layer known as *poliment*, made of red or orange-red pigments, a small amount of soap, wax and egg protein. Different methods of preparation of this material existed, but the basic components were common and could include pigments such as raw or burned ochre, red earth, minium and in later years, armenian bole. During the 17th century, Moscow pigment merchants offered a ready-to-use mixture under the exact name. According to the same sources, the shell gold technique gradually seems to have replaced the use of mordant gilding in the delicate decorations of Russian icons from the17th century [5] (pp. 27–28, 48).

3.6. Paint Layers

3.6.1. Pigments

For pigment identification, the distinct chromatic regions in the visible were compared to their hue under different imaging conditions. A typical set of imaging results is demonstrated in Figure 7. This procedure led to an initial estimation of the pigments used per chromatic region, but also to a more accurate distinction among regions of a similar hue in the visible spectrum, that procured different false colours. The grey tones in #14147 present a good example. They differentiated under IRRFC imaging, were analysed separately and were found, on a case-by-case basis, to comprise of verdigris, azurite or ochre, mixed with lead white and carbon black. (Figure 11).

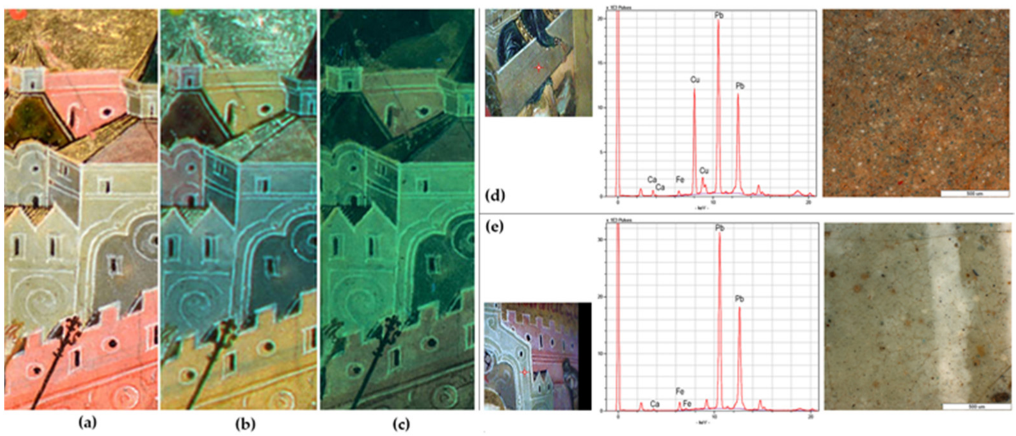


Figure 11. Triptych inv. no. 14147. Detail of the Annunciation: (**a**) VIS, (**b**) IRRFC, indicating the use of different mixtures in the rendering of the grey buildings, (**c**) UVL, (**d**) #3 and (**e**) #17 points of analysis, acquired XRF spectra and micro images, respectively, confirming the use of verdigris and iron oxides mixed with lead white and carbon black. © Benaki Museum Conservation Department.

Conclusions relating to the use of pigments and dyes are presented separately for each artefact in Tables 1 and 2. Lead white, carbon black, iron oxides, cinnabar, azurite, malachite, copper green (verdigris), green earth, umber, orpiment, red lead (minium), ultramarine, indigo or woad and red lake were identified. Based on the examination of literary sources, this palette is expected but does not exploit all available means.

Table 1. Use and distribution of pigments and colourants [1].

Pigments	#14126	#14147	#14461	#29534 & #29535
Lead white	•	•	•	•
Carbon black	•	•	•	•
Iron oxides	•	•	•	•
Cinnabar	•	•	•	•
Azurite	•	•		•
Malachite	•	•	•	
Copper green (Verdigris)	•	•	•	
Green earth	•	•		•
Umber				•
Orpiment				•
Minium	○	○	○	○
Ultramarine		○		○
Indigo/woad		○		•
Red lake	•	•	•	

[1] •: identified, ○: strong indication.

XRF analysis cannot not procure evidence on the use of ultramarine, and due to the non-invasive nature of the proposed methodology and limitations of the research requirements relating to the use of simple and readily available means, no analysis of organic matter was carried out. Nevertheless, there are strong indications supporting the use of ultramarine in the rendering of blue garments of the #14147 and the polyptych wings, but also of indigo/woad and red lake in a number of areas. These resulted from imaging (Figures 6, 7 and 10) and the lack of identified elements in the respective points of analysis. The deep, bright red IRRFC recorded in areas corresponding to blue garments in the side panels (Figure 6a) indicates the use of ultramarine and/or indigo/wood, while the pinkish orange fluorescence (Figure 7c) and golden yellow IRRFC (Figure 7a) of the Virgins maphoria in #14126 could be related to the use of red lake. In this context, in Table 1, such colourants have, in most cases, been given a "strong indication" mark. In Table 2, where an unambiguous characterization of the used colourants could not be safely achieved, possible alternatives are recorded. As with the applied methodology, the use of minium in areas modelled with cinnabar and lead white cannot be safely ruled out, it is included in the list of those used. The reader is nevertheless urged to handle this information with some caution.

Distinction between pigments containing common elements, based on imaging and XRF, may sometimes raise concerns, particularly in the case of mixtures or overlapping paint layers. Although in such instances, line scan results, visual examination and imaging on a micro scale provided useful insights, it should be noted that the contribution of the latter, on a case-by-case basis, also depends on the size of the pigment particles under investigation and their distribution within the paint strata.

Table 2. Use of colourants per chromatic region [1].

Colour/Area Description	#14126	#14147	#14461	#29534 & #29535
Browns & salmon pinks Faces & flesh parts	U: red iron oxides, lead white, green earth, carbon black and copper green or blue MT: lead white, iron oxide, cinnabar	U: iron oxides, lead white, green earth MT: lead white, iron oxide S: iron oxide, cinnabar	U: yellow ochre, lead white, carbon black MT: iron oxides, lead white H: lead white	Iron oxides, lead white, cinnabar, green earth U: also includes umber
Red garments	U: cinnabar, lead white S: lake	Cinnabar S: lake	U: cinnabar plain or with lead white or minium, carbon black	Cinnabar, lead white and/or minium, iron oxides and/or green earth
Orange garments		Iron oxides, cinnabar, lead white, carbon black		Iron oxides, lead white, cinnabar
Orange (Salmon) garments		Lead white, red lake, iron oxides, azurite		
Pinks	*Table cover* U: lead white, cinnabar, carbon black S: iron oxide	*Building* U: lead white, cinnabar, azurite	*Building* Lead white, cinnabar	
Purple maphoria	Red lake	Red lake, iron oxide, carbon black	Red iron oxide, azurite, lake	
			U: lead white, red iron oxide Sc: red lake	
Purple garments			U: red iron oxide, lead white, azurite, carbon black	Lead white, cinnabar, umber and/or iron oxides, possibly green earth and lake
Ochres	*Mountain* Iron oxides, lead white, carbon black S: lake		*Horse* Lead white, yellow ochre	
Browns	*Garments* Azurite or malachite, *chervlen* or lake, green earth or iron oxides	*Hair* U: iron oxides, lead white, carbon black		*Wings, garments* U: umber, possibly red iron oxide, lead white, carbon black, copper blue or green pigment, green earth
Blue garments		Azurite, verdigris or indigo/woad		Ultramarine or indigo/woad, lead white, iron oxides
Blues	*Sky* Lead white, carbon black	*Building* Lead white, azurite, verdigris, cinnabar		
Green garments	Verdigris, lead white	U: green earth, lead white, possibly iron oxides	Malachite, lead white, iron oxides	U: lead white, green earth, orpiment, cinnabar, umber
			U: verdigris S: iron oxides, lead white or minium	
Green mountains	Verdigris, lead white, green earth or carbon black	U: lead white, iron oxides, cinnabar S: green earth, carbon black		
Greens	*Sky* Lead white, azurite *Background* Verdigris, lead white *Water* Verdigris, green earth	*Leaves* Malachite, iron oxides		
Greys		*Building* U: lead white, iron oxides, carbon black		*Garment* Lead white, green earth, cinnabar, carbon black
		Hair Lead white, iron oxides, green earth		
		Tomb stone U: lead white, verdigris, carbon black		
White garments	Lead white	Lead white		Lead white, iron oxides, carbon black
Blacks		*Horse* U: carbon black, lead white, iron oxides		*Background* Carbon black, lead white, umber and/or iron oxides
		Ground U: carbon black, iron oxides and/or green earth, lead white		

[1] U: underpaint, MT: mid-tone, H: high-light, S: shadow, Sc: scumble.

3.6.2. Painting Techniques

The Painting of the Faces and Flesh Parts

Two types of pigment mixtures were identified as underpaints of the faces and flesh parts and distinctively recorded by IRRFC and IRR imaging. The first, used in the #14126 and #14461 triptychs, consists of yellow ochre and black, with the addition of small amounts of green earth or azurite; it is considered typical of old Russian icons [33] (pp. 34–35), [36] (p. 25). It is recorded with a greenish hue in IRRFC imaging (Figure 7a) and high absorptions in IRR (Figure 7d), respectively, relating to the ochre and black pigment content.

The flesh underpaints of #14147 and the two polyptych wings are made of *sankir* (санкирь). This is a mixture of yellow, red ochres and green earth, which is expected in Russian icons produced after the 16th century [4] (p. 32). Due to its high content in green earth, such underpaints are recorded with much warmer tones in IRRFC images (Figures 6a and 10c), but also with lower absorptions in IRR (Figures 6b and 10b), as they include no black.

On a case-by-case basis, the modelling was also found to deviate from the standard technique. In #14126, the expected sequence of execution of mid-tones and highlights is reversed (Figure 12d,e). Anatomical details are formed in white, directly over the brown underpaint, and then almost completely covered with a pink tone that unifies the shapes and softens sharp transitions of tonality. Some parts of the white configuration (e.g., the tip of the nose, the upper lip and the cheekbones) are left uncovered, functioning as highlights on the finished work. Shading is practically replaced by uncovered areas of the underpaint. Fine brushstrokes of a dilute, orange-coloured paint, sparingly applied between the pink mid-tone and the underpaint is used as blush. In #14147 (Figure 12c), passages of a warm-coloured tone, indiscriminately used for shading and blush, are found preceding the application of the mid tone. Although the support of such particularities has not yet been achieved based on literary sources, it is estimated that to some extent they may relate to the small scale of the depictions and an attempt to achieve smooth transitions of tonality. In #14461, where the modelling faithfully follows the standard technique (Figure 12a), UVL imaging (Figure 12b) shows application of an orange-coloured layer of high transparency over the finished faces and flesh parts which possibly serves the same purpose.

The Painting of Garments

In most cases, regardless of scale, the seemingly simply rendered garments are modelled according to the system typical of Russian icon painting, exploiting four shades forming pairs of similar tonality and composition [4] (pp. 53–54) (Figure 13a–c). Although well recorded via UVL imaging (Figure 10d), they are discerned with difficulty under other imaging techniques, as in each pair of shades the composition of the pigment mixtures varies only slightly. The deep orange-coloured garments of triptych #14147 (Figure 10) present good examples.

A different technique is based on the use of the underdrawing beneath colour passages of medium or high transparency (Figures 9c and 13g–i). Here, the underdrawing contributes significantly to the shading and the modelling of the draperies. This technique was also used in triptych #14126. In such small-scale depictions, the parallel exploitation of such different techniques, used side by side on garments rendered with either gold highlights over opaque underpaints (Figure 13e), or dark fine lines and coloured organic glazes over burnished gold or silver leaves (Figure 13d), has led to a rich, highly decorative result.

Figure 12. Details of flesh areas demonstrating particularities and deviations from the standard technique: (**a**) VIS and (**b**) UVL of inv. no. 14461, (**c**), micro imaging, inv. no. 14147, Gabriel's head, (actual height: 0,52 cm), (**d**,**e**) micro imaging, inv. no. 14126. © Benaki Museum Conservation Department.

Figure 13. Details of garments, inv. no. 14147, demonstrating particular rendering techniques, (**a**–**c**) use of four shades, (**d**) fine lines and glazings over burnished gold, (**e**) gold striations over the Virgins purple *maphorion*, (**f**) contrasting colours, (**g**–**i**) exploitation of the underdrawing under transparent and semi-transparent underpaints. © Benaki Museum Conservation Department.

In the #14461, two techniques using similar pigment mixtures and gold, either in the form of burnished leaves or as emulsions, have led to an unusually painterly result. Where garments are modelled over burnished gold (Figure 14a–c), any gold left uncovered functions as a highlight, with the paint occupying only the edges of the rendered shape. Surfaces covered by metal appear solid and boundaries between gold and colour are sharp. Where the same paint mixtures are used directly over the ground (Figure 14d–f), highlights are rendered with gold emulsion. The technique is easily discerned due to the gradual fading of the gold striations.

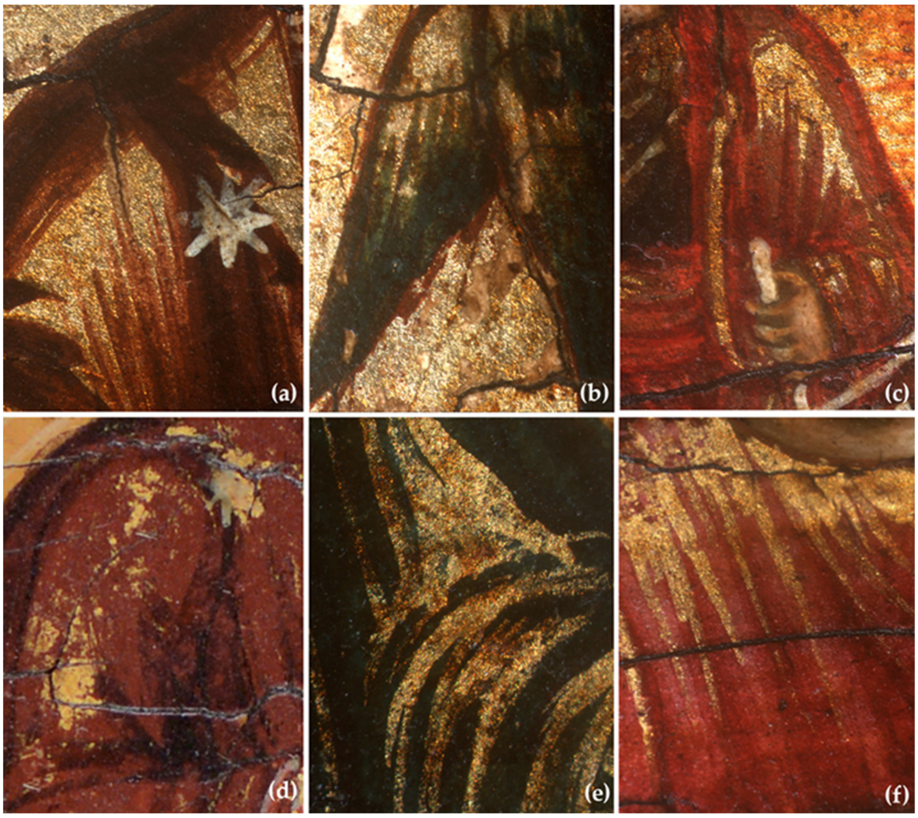


Figure 14. Details of garments, inv. no. 14461, (**a**–**c**): paint applied over burnished gold leaves, (**d**–**f**): gold striations applied over similar paint mixtures. © Benaki Museum Conservation Department.

4. Evaluation

The proposed methodology proved very effective in terms of its output, the integrated approach of the construction techniques, and the simple, user-friendly and low-cost technologies applied, but also time consumption factors relating to the acquisition and interpretation of the results.

Despite the non-invasive, non-destructive character of the procedures, detailed information relating to almost all the construction levels was recorded. Most of the inorganic constituents were identified, and a description of the process followed in the making of the composite artefacts was achieved. The lack of detailed information relating to stratigraphy was to some extent compensated for by the meticulous combined utilization of XRF results, visual examination and imaging on a micro scale. Nevertheless, the addition of μRaman to the methodology scheme, implemented non-invasively for the study of surface mixtures, will undoubtedly add to the result.

Organic constituents, such as the binding medium, dyes and coloured glazes, comprising a distinct, rather complicated and up to now uncharted field in the technology of late Russian icon painting, are difficult to identify without sampling. Although information on glazes is considered basic in order to fully understand the handling of colour, in the context of this "pilot' project, which prioritizes the gradual build-up of a structured, solid base of knowledge to be exploited for the further study of icons, it is not considered a handicap. A most valuable side-effect of the procedure was the compilation of a base of technical information on Russian icon painting, derived from literary sources, that will undoubtedly contribute to future projects.

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