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Wilhelm Kotarbinski's sketches for the murals of St. Volodymyr's Cathedral: A multi-analytical approach to the artist's painting materials study

Abstract. Wilhelm Kotarbinski (1848-1921) is an outstanding modernist Ukrainian artist of the late 19th and early 20th centuries who became widely known after painting murals in St. Volodymyr's Cathedral in Kyiv. Kotarbinski's sketches are an important part of his graphic heritage that plays a great role in understanding the artistic technique and his approach to creating murals. The purpose of the work was a comprehensive study of the painting materials of Wilhelm Kotarbinski's four sketches for the murals of the Small Dome of St. Volodymyr's Cathedral depicting seraphims and the introduction of the results into scientific circulation. The methodology was to apply a multi-analytical approach that included non-destructive analytical methods such as technical photography in different spectral ranges, microscopic examination, X-ray fluorescence analysis, and Fourier transform infrared spectroscopy. The presented work was the first comprehensive study of Wilhelm Kotarbinski's drawings, which aimed to establish the artist's technique and the technological characteristics of the paper support and to identify pigments in the paint layer. The results indicated that Italian-made paper was used as the sketches' support, which characterised the same fiber and elemental composition. The paper support was made of cellulose obtained from annual plants, sized with animal glue, and contained gypsum and kaolin as fillers. The fluorescence characteristic of the sketch paper, the established elemental composition, and the comparative analysis of the degree of aging indicate that the paper was produced in the last quarter of the 19th century. It was shown that the execution technique of drawings consisted of the preliminary application of detailed underdrawings with a graphite pencil, including compositional lines. It was established that the sketches were painted with watercolors, and the pigments in the paint layer of the drawings were identified. The obtained results are an essential contribution to the existing body of knowledge about late 19th century artists' materials and could be useful in researching and attributing studies of Wilhelm Kotarbinski's graphic works

Keywords: drawing; painting technique; non-destructive analysis; technical photography; X-ray fluorescence analysis; Fourier transform infrared spectroscopy

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Introduction

The study's relevance lies in obtaining valuable information about Wilhelm Kotarbinski's drawings that will contribute to a deeper understanding of the artistic techniques and materials used to execute the murals for St. Volodymyr's Cathedral in Kyiv.

Wilhelm Kotarbinski (1848-1921) is one of the most prominent artists of modernist painting of the late 19th and early 20th centuries. His artistic heritage includes dozens of paintings, hundreds of watercolors, sepia paintings, and drawings. The figure of Kotarbynskyi and his contribution to the development of Ukrainian fine art have been neglected by art historians for decades as noted V. Sukovata (2021). The emergence of research projects devoted to studying Kotarbinski's biography, cataloging his artwork, and stylistic analysis of the artist's oeuvre was marked before 2021 when the artist's death anniversary was celebrated.

The study of T.A. Galkevich & O.D. Donets (2019) was devoted to the attribution of photographic documents stored in the Department of Fine Arts of the Vernadsky National Library of Ukraine and directly related to the life and work of Kotarbinski as well as clarification of artist's biographical information. The analysis of the influence of English art of the second half of the 19th and early 20th centuries on artist's work and the differences in the embodiment of decadent and symbolist tendencies of Ukrainian and Polish artists was conducted by O. Sosik (2019). Also, O. Sosik (2020) studied the influence of the historical method and eclectic trends on the peculiarities of the implementation of new stylistic trends in the ancient Egyptian and ancient painting of Wilhelm Kotarbinsky. O. Pelikhovska (2021) analysed the influence of the Spanish artist Mariano Fortuny (1838-1874) on Kotarbinski's artwork, presented a comparative analysis of the artists' paintings, revealed reinterpretations and borrowings of compositional solutions and scenes in Polish artist's works. The systematisation of the monumental works Kotarbinski from the Khanenko Museum's collection and their art and attributive analysis were provided by O. Sakorska (2021b). The scenes of the artist's Far Eastern and Egyptian temples from the Khanenko museum interiors were carefully analysed in the essay O. Sakorska (2021a) and the sources of his inspiration were found and shown. Various aspects of the artist's life and work were highlighted in the "Antykvar" magazine edited by H. Sherman (2021) and a special issue of the collection of scientific papers "Wilhelm Kotarbinski: Unexplored pages of his life and work" (Synyshyn & Strokal, 2021). The results of the study of archival sources carried out by V. Ulianovskyi (2021) made it possible to establish which scenes of the St. Volodymyr's Cathedral's murals were created by Kotarbinski on his own and which were in collaboration with Pavlo Svedomskyi and other artists. However, the use of technological research in the examination of the artist's works is still minimal. Existing publications mainly focused on the study of his paintings and were based on visual analysis.

The purpose of the study was to provide a comprehensive examination of the artist's materials of Wilhelm Kotarbinski's sketches and introduce the results to scientific circulation. The main focus of the research was on establishing the technological features of the paper support and the drawings' execution technique, as well as determining the pigment palette of the paint layer of the sketches.

Materials and Methods

Wilhelm Kotarbinski's studied drawings (Figs. 1-4) were sketches of seraphims for the murals of the Small Dome of St. Volodymyr's Cathedral (images of the paintings were given in the album (Drobotiuk, 2014). The sketches come from the Prakhov family and belong to the Spiritual Treasures of Ukraine Museum collection. According to the museum's attribution, they were created in the 1880s.

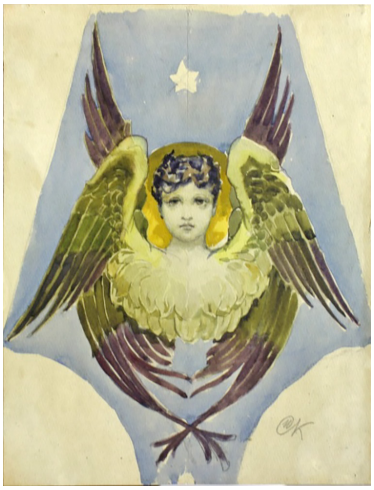

Figure 1. Wilhelm Kotarbinski. Seraphim. Sketch No. 1. 1880s. 326×255 mm. Paper, graphite pencil, watercolour
Source: Spiritual Treasures of Ukraine Museum collection

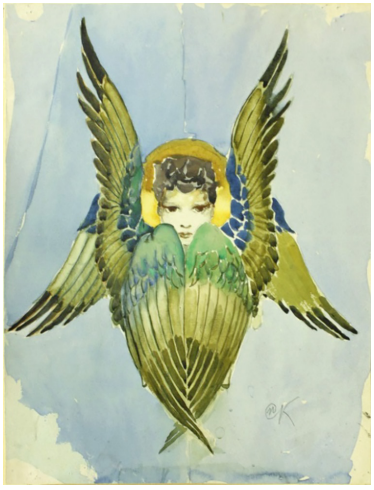

Figure 2. Wilhelm Kotarbinski. Seraphim. Sketch No. 2. 1880s. 326×254 mm. Paper, graphite pencil, watercolour
Source: Spiritual Treasures of Ukraine Museum collection

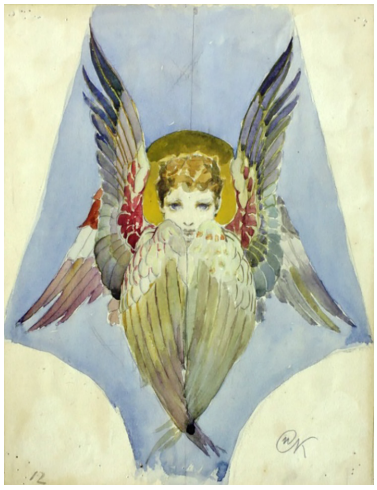

Figure 3. Wilhelm Kotarbinski. Seraphim. Sketch No. 3. 1880s. 327×254 mm. Paper, graphite pencil, watercolour, gilding
Source: Spiritual Treasures of Ukraine Museum collection

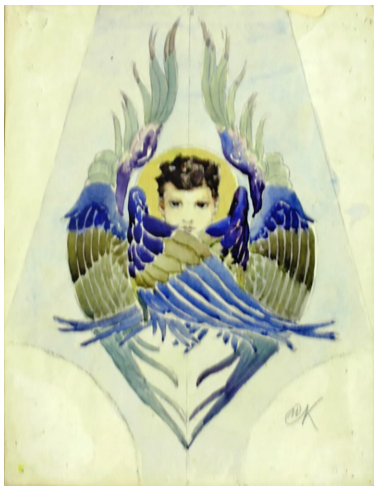

Figure 4. Wilhelm Kotarbinski. Seraphim. Sketch No. 4. 325×255 mm. Paper, graphite pencil, watercolour, gilding
Source: Spiritual Treasures of Ukraine Museum collection

Wilhelm Kotarbinski worked on the murals in St. Volodymyr's Cathedral from 1889 to 1894 together with Pavlo Svedomskyi, creating 18 compositions, 84 individual figures, and some of the ornaments (Dobriian, 2015). While working on the murals, the artists made numerous preliminary drawings. The sketches for the murals were executed in Rome, from where Kotarbinski and Svedomskyi brought nine cartoons to Kyiv.

This paper proposed a comprehensive multi-analytical approach to the study of Wilhelm Kotarbinski's sketches, which aimed to establish the technological characteristics of the drawings' support, identify the pigments of the paint layer, and determine the author's execution technique. It included optical and physicochemical methods (Andrianova *et al*., 2018; Andrianova *et al*., 2020) such as examination in visible and transmitted light, ultraviolet and infrared ranges, optical microscopy, X-ray fluorescence analysis, and Fourier transform infrared spectroscopy. These research methods were non-destructive in the case of artwork on paper support, which was a priority in studying cultural heritage objects.

Due to the unique character of the present artworks, optical and physicochemical analytical methods have been selected for carrying out research. Preliminary examination by a microscope, in visible ranking and transmitted light, and ultraviolet (UV) radiation (Buzit Tragni *et al*., 2005) have been performed to investigate the conservation state of the drawing. Infrared (IR) imaging has been used for studying underdrawing techniques (Fontana *et al*., 2018). Observation in UV and IR radiation was carried out for preliminary identification of pigments in paint layers (Cosentino, 2015; 2016). The imaging in different spectrum ranges was performed using a modified multispectral (360-1100 nm) Canon Rebel XSi camera (Canon Inc., USA) with a resolution of 12.2 Mpx. The study of UV-induced fluorescence of drawings' materials was conducted in a dark room using UV radiation sources of 36W UV bulbs (wavelength band 320-400 nm) equipped with uviol glass filters. Imaging in the near-infrared range (1000 nm) was conducted using a Pro-HD IR1K filter mounted on the camera lens and 500 W incandescent lamps as sources of infrared radiation. Microscopic examination was carried out using a stereoscopic microscope MBS-10 and a digital microscope SigetaExpert (Sigeta Optics Ltd., Ukraine) with a resolution of 5.0 Mpx.

X-ray fluorescence analysis (XRF) has been executed to obtain the elemental composition of the paper supports (Manso & Carvalho, 2009), drawing materials and paints (Doleżyńska-Sewerniak *et al*., 2020). The measurements were performed for 200-300 s using an ElvaX-ART spectrometer (Elvatech, Ukraine) with an SSD detector and a W anode X-ray tube with 35.0 kV voltage and 50 μA current. The spectra were processed automatically with ElvaX 2.9 software.

Fourier-transform infrared spectroscopy (ATR-FT-IR) was widely used for the identification of paper fiber origins and the chemical structure of the sizing and fillers (Kumar *et al*., 2017). The paper supported composition was determined with a Vertex 70 spectrometer (Bruker, Germany) equipped with a diamond-attenuated total reflectance accessory (ATR) with diamond. Spectra collection and processing were carried out using OPUS 6.5 software. The spectra were acquired in the spectral range of 400-4500 cm^{-1} with an accuracy of 0.5 cm^{-1}. The spectra were recorded at a resolution of 4 cm^{-1}. A total of 64 scans were recorded for each sample. The pain layer and paper composition were identified by comparative analysis with the FTIR spectra of standard samples of pigments (Kremer Pigments Inc., Germany), European manufacturers' paints (Industria Maimeri, Italy; Royal

Talens, The Netherlands; Lefranc & Bourgeois, France; Winsor & Newton, England), and painting materials (fibers, glues, and binders) from the Bureau of Scientific and Technical Expertise "ART-LAB" database.

Since the 2010s, considerable attention has been paid to the investigation of paper degradation mechanisms. There were a variety of published research works proposing FTIR as an analytical technique to study aging of papers (Chiriu *et al*., 2018; Silva *et al*., 2022). Studying paper aging by FTIR analysis was a comprehensive process due to the influence of different factors related to storage conditions (e.g. temperature, humidity, UV-radiation exposure) and the complexity of paper composition (cellulose, hemicellulose and lignin, sizing, and fillers) that subject the degradation process to different mechanisms. The degradation process of cellulose was usually observed in the infrared spectrum in the region of 1600-1700 cm^{-1} region which corresponded to the stretching vibrations of C = O groups. Absorbance peaks were characteristic of carbonyl compounds that being formed during the degradation process and increase with aging (Zięba-Palus *et al*., 2017). Information about structure changes of calcite and kaolin as fillers in paper composition and their influence on the degradation process also was given by this author. These techniques provide useful data regarding the composition of paper and pigments and allow to determine the creation time of objects on paper support.

The applied analytical methods were engaged to obtain information about the artist's technique, characteristics of the painting materials, and the time of the sketchers' execution.

Results and Discussion

The study focused on examining signatures' characteristics, establishing the technological features of the paper support, the drawings' execution technique, and the pigment palette of the sketches. All the sketches are signed at the low right corner of the sheets with the monogram "WK". The signatures were applied with a graphite pencil with a thin stem. The signature of the *Seraphim. Sketch No. 3* was re-drawn with a thicker stem pencil. The sketches were made on 2 mm thick paper sheets mounted on the cardboard sheets. Paper supports have acquired an uneven yellow-brown tint due to the natural aging and deterioration with time. The edges of the sheets appear darker than the rest of the paper due to the oxidation of cellulose under light exposure. Paper fading in the corners is caused by the influence of the glue used to attach the sheet to the cardboard. No deformations of the sheets, losses, breaks, and slits were observed. The numerous tack holes at the corners indicate that the artist pinned the drawings' sheets to a board or tablet while sketching.

Microscopic examination has shown that the author used fragments of a larger sheet to create the drawings, as indicated by the uneven edges of the paper supports cut with a tool with sharp blades. In visible transmitted light, the fibers in the paper were found to be unevenly distributed. The sheets had a cloudy gap, indicating that their structure was not uniform. No watermarks or paper manufacturer's marks were observed. Under UV radiation, the paper sheets are characterised by a slight fluorescence of a light purple hue, typical for paper made in the second half of the 19th century (Andrianova *et al*., 2018). No restoration interventions or retouchings have been detected in the UV range.

The paper supports have a dense surface with a faint, fine-grained texture. Microscopic examination of the paper fiber composition (Fig. 5) and ATR-FTIR analysis has shown that the sketches' supports are machine-made paper produced of annual plant cellulose (no lignin was determined in the paper). The sheet surface is sized with animal glue, a characteristic feature of paper made before the early 20th century (Manso *et al*., 2011).

Figure 5. Seraphim. Sketch No. 1.
Optical microscopy image of fibers in paper composition (magnification ×150)
Source: authors' photo

The XRF method (Manso & Carvalho, 2009; Andrianova *et al*., 2018) was determined the elemental composition of the sketches' paper (Table 1). The main elements in the paper composition are Fe (iron), Ca (calcium), and K (potassium). Small amounts of Zn (zinc), Pb (lead), Rb (rubidium), and Cu (copper) are identified in papers, as well as micro amounts of strontium (Sr) compounds. Obtained elemental composition, the absence of manganese compounds and identified small amounts of lead are typical for paper produced in the last third of the 19th and early 20th centuries (Andrianova *et al*., 2020). The presence of potassium and rubidium compounds indicates the applications of kaolin as a filler (Doncea *et al*., 2009; Pitarch *et al*., 2012), and strontium compounds are natural impurities in chalk and gypsum (Pitarch *et al*., 2012), which was confirmed by ATR-FTIR – kaolin and gypsum were used as paper fillers. According to the M. Manso *et al*. (2011), using gypsum as a filler is typical

of Italian-made paper (perhaps the paper was purchased by the artist in Rome). The obtained data indicate that the author used the same manufacturer paper and, possibly, the same album sheets when creating drawings.

Table 1. Elemental composition of Wilhelm Kotarbinski's sketches' paper supports

Sketch number	Elemental composition, %							
	Fe	Ca	K	Zn	Pb	Rb	Cu	Sr
1	43	29	19	3	2	2	2	0.6
2	42	31	16	2	1	1	4	0.7
3	44	28	14	3	9	2	1	0.4
4	46	26	18	3	2	2	2	0.6

Source: developed by authors

To assess the degree of the drawings supports' aging, ATR-FTIR analysis was carried out according to the method described in work of O. Andrianova *et al.* (2020) and infrared spectra of drawings' paper were compared with the spectra of paper of reference-dated works of the 19th and first quarter of the 20th centuries. It was established that the paper's production corresponds to the last quarter of the 19th century when Wilhelm Kotarbinski worked on sketches for the murals in St. Volodymyr's Cathedral. Underdrawings applied with a graphite pencil are visible throughout (Fig. 6), either along the edges of some imaging details or through thinly painted layers during microscopic examination of the sketches.

Figure 6. Seraphim. Sketch No. 4.
Optical microscopy image of underdrawings, applied by graphite pencil (magnification ×50)
Source: authors' photo

Near-infrared imaging confirmed that extensive underdrawings outline the entire composition, including lines of the central vertical axis, external contours of the composition, and a detailed drawing of the sketches' scene (Figs. 7-8). There are further author edits with watercolors of the initial drawing made with a graphite pencil.

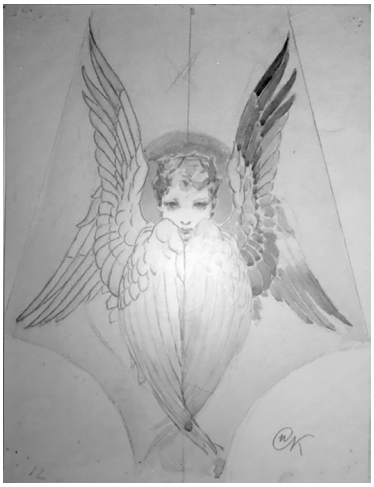

Figure 7. Seraphim. Sketch No. 3.
Near-infrared range image
Source: authors' photo

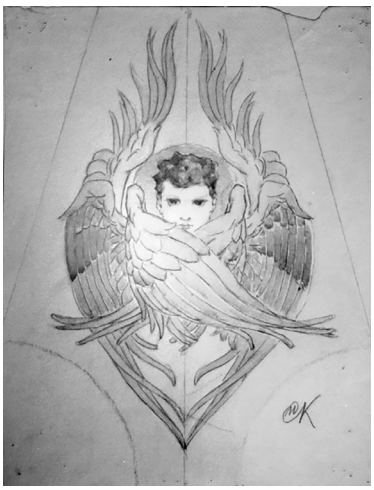

Figure 8. Seraphim. Sketch No. 4.
Near-infrared range image
Source: authors' photo

The paint layer is thin and applied with watercolors of homogeneous factory grinding. Sketches No. 3 and 4

are supplemented with brushstrokes of a gold-colored metallic paint. Microscopic studies of dense painting brushstrokes revealed a few craquelures with wide edges caused by the aging of the paint binder.

Examination of the sketches in the UV and IR ranges provided preliminary information about the nature of the pigments used by the author, which was considered in further physicochemical studies. The following pigments were identified in the paint layers by XRF and ATR-FTIR analysis: chromium yellow (lead chromate), zinc yellow (zinc chromate), vermillion, alizarin crimson, ocher, umber, Emerald green (copper acetoarsenite), cobalt blue, Prussian blue, and ultramarine blue (the pigment palette of Wilhelm Kotarbinski's sketches is given in Table 2). No white pigments were determined in paint layer composition. It is known that chrome yellow was introduced in the early 19th century (Kuhn & Curran, 1986) and was included in the list of essential colors for watercolor painting in the 1850s (Harley, 1987). H. Kuhn & M. Curran (1986) investigated the origin of zinc yellow and determined that this color was first synthesized around 1800s, but was not used until mid-century and was not widely used thereafter. Vermillion was manufactured since antiquity and produced industrially until the mid-20th century (Melo & Miguel, 2010). As noted I. Degano *et al.* (2017), synthetic alizarin was obtained in 1868 and became popular shortly after that. Emerald green pigment was industrially produced in 1814 (Herm, 2020) and was commonly used in oil painting until the 1960s despite its toxicity (Fiedler & Bayard, 1977). Cobalt blue, Prussian blue, and ultramarine blue have been widely used in the 19th century and are popular till now. It should be noted that in cobalt blue composition were detected small amounts of nickel possibly as a natural admixture of cobalt-containing ores. J. Hradilová *et al.* (2020) noted, that the presence of nickel in paint could be explained by insufficiently efficient raw material purification procedures in the 19th century. The greenish-brown image details are depicted with a mixture of chrome yellow, zinc yellow, and cobalt blue. The purple tint paints included Prussian blue (mixed with cobalt blue or ultramarine) and vermilion or alizarin crimson. Gold was detected in gold-colored metallic paint composition. All identified in the artist's palette pigments are typical for the late 19th and early 20th century watercolor painting. Plant gum (gum arabic) was identified as a paint binder in all paints.

Table 2. Pigment palette of Wilhelm Kotarbinski's sketches paint layer

Sketch number	Detected pigments									
	Chrome yellow	Zinc yellow	Vermillion	Alizarin crimson	Ochre, umber	Emerald green	Cobalt blue	Prussian blue	Ultramarine	Gold
1	+	+	+	+	+		+	+		
2	+	+	+		+	+	+			
3	+		+		+		+	+	+	+
4	+	+	+	+	+		+	+	+	+

Note: the symbol + indicates the presence of the pigment in the sketch's paint layer, an empty cell – the absence of pigment
Source: developed by the authors

Thus, technological research of the Seraphim sketches for the murals of the Small Dome of St. Volodymyr's Cathedral made it possible to establish the morphological characteristics, elemental and fiber composition of the paper supports and to identify the pigments of the paint layers. The results indicate that the drawings were executed in the last quarter of the 19th century, confirming the museum's attribution.

The presented work was the first comprehensive research of Wilhelm Kotarbinski's drawings, which aimed to establish the technological characteristics of sketches, such as the paper support features, the author's execution technique, and the pigment palette of the paint layer.

Conclusions

A comprehensive technical study was carried out on four Wilhelm Kotarbinski's sketches of seraphims for the murals of the Small Dome of St. Volodymyr's Cathedral. The study involved employing non-destructive analytical methods such as technical photography in various spectral ranges, microscopic examination, X-ray fluorescence analysis, and Fourier transform infrared spectroscopy to characterise the artist's painting materials and technique. All the sketches are signed with the monogram "WK" applied with a graphite pencil. The study revealed that the artist used Italian-made paper as the drawings' support characterised by a consistent fiber and elemental composition. Papers' fiber and elemental composition were determined as well as the types of sizing and fillers. It was shown that the drawings' support is composed of cellulose derived from annual plants, sized with animal glue, and includes gypsum and kaolin as fillers. The fluorescence properties, elemental composition, and comparative aging analysis suggest that the sketchers' papers were produced in the late 19th century. The study demonstrates that the drawings were executed with detailed underdrawings in graphite pencil, including compositional lines, followed by watercolor application. Chromium yellow (lead chromate), zinc yellow (zinc chromate), vermillion, alizarin crimson, ocher, umber, Emerald green (copper acetoarsenite), cobalt

blue, Prussian blue, ultramarine blue, and metallic gold were identified in paints and paint mixtures. All investigated pigments were bound in plant gum.

A comprehensive study of the drawings allowed to confirm the museum's attribution and establish the technological features (paper support composition, the underdrawings' technique, and the color palette) inherent in the artist's work of the late 19th century. This information may assist art historians and curators in authenticating and attributing Wilhelm Kotarbinski's graphic art. Prospects for further research are related to the exploring artist's approach to the execution of easel paintings and studying his artwork from Ukrainian museums and private collections applying modern analytical techniques.

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Conflict of Interest

None.

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Ескізи Вільгельма Котарбінського до розписів Володимирського собору: мультианалітичний підхід до вивчення малярських матеріалів художника

Анотація. Вільгельм Котарбінський (1848-1921) – видатний український художник-модерніст кінця XIX – початку XX століть, який став широко відомим після розпису Володимирського собору в Києві. Ескізи Котарбінського є важливою частиною його графічної спадщини, яка відіграє велику роль у розумінні художньої техніки та його підходу до створення стінописів. Метою роботи було комплексне дослідження живописних матеріалів чотирьох ескізів Вільгельма Котарбінського до розписів Малої бані Володимирського собору із зображенням серафимів та введення отриманих результатів у науковий обіг. Методологія дослідження полягала у застосуванні мультианалітичного підходу, що включав неруйнівні методи аналізу, такі як технічна фотографія в різних спектральних діапазонах, мікроскопічне дослідження, рентгенофлуоресцентний аналіз та інфрачервона спектроскопія з перетворенням Фур'є. Представлена робота була першим комплексним дослідженням малюнків Вільгельма Котарбінського, яке мала на меті встановити техніку художника та технологічні характеристики паперової основи, а також ідентифікувати пігменти у фарбовому шарі. Результати дослідження вказали на те, що в ролі основи для ескізів використовувався папір італійського виробництва, який характеризувався однаковим волокнистим та елементним складом. Паперова основа виготовлена з целюлози, отриманої з однорічних рослин, проклеєна тваринним клеєм і містила гіпс та каолін як наповнювачі. Флуоресцентна характеристика ескізного паперу, встановлений елементний склад та порівняльний аналіз ступеня старіння вказали на те, що папір був виготовлений в останній чверті XIX століття. Показано, що техніка виконання малюнків полягала у попередньому нанесенні детальних прорисів графітним олівцем, включаючи композиційні лінії. Встановлено, що ескізи були виконані аквареллю, а також ідентифіковано пігменти у фарбовому шарі малюнків. Отримані результати є суттєвим внеском в наявний масив знань про матеріали художників кінця XIX століття і можуть бути корисними при дослідженні та атрибуції графічних творів Вільгельма Котарбінського

Ключові слова: малюнок; техніка живопису; неруйнівний аналіз; технічна фотографія; рентгенофлуоресцентний аналіз; інфрачервона спектроскопія з перетворенням Фур'є