ANASAY 2025, Yıl 9, Sayı 31, 80-106, DOI:10.33404/anasay.1614702

e-ISSN: 2618-6187

https://dergipark.org.tr/tr/pub/anasay

COPYING AND FORGERY IN OIL PAINTINGS: RESEARCHING AND APPLICATION EXAMPLE OF IDENTIFICATION OF AUTHENTICITY BY SCIENTIFIC ANALYSIS[1]

YAĞLIBOYA TABLOLARDA KOPYA VE SAHTECİLİK: BİLİMSEL ANALİZLERLE ÖZGÜNLÜK TESPİTİNİN ARAŞTIRILMASI VE UYGULAMA ÖRNEĞİ

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Abstract

In this study, an unsigned oil painting from the Istanbul University Faculty of Letters collection, featuring an unknown painter and date, was subjected to dating and authentication processes. The painting exhibits a landscape on one surface and a nude female portrait on the other. Both surfaces were examined using visible light (VIS), raking light (RAK), ultraviolet (UV), and infrared (IR) light sources. For organic and inorganic pigment analyses, High Performance Liquid Chromatography (HPLC) and Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy (SEM-EDX) were employed. Fourier Transform Infrared Spectroscopy (FTIR) was utilized for binder and primer layer analyses, and a stereo microscope was used for fiber analysis. Additionally, dendrochronological analysis was conducted to determine the type of wood and age of the painting's chassis. Art historical research provided insights into the painting's stylistic and technical aspects, as well as the artistic features of the composition, despite the unknown artist and year. HPLC analysis within the scope of pigment research indicated[2] the absence of organic pigments, while SEM-EDX analysis identified ultramarine, cadmium red, manganese oxide, guignet green, lead red (minium), zinc white, lead white, Verona green, ivory/bone black, lithopone, molybdate red, permanent white, Prussian blue, Brunswick green, zirconium oxide, and black iron oxide. FTIR analyses have determined that the binder used in the paints of the painting is linseed oil. Fiber analysis determined that the canvas was made of linen. Dendrochronological analysis of the chassis dated it to 1913, although it was noted that processed wood could not be precisely dated. All analytical results were evaluated to establish an approximate date for the painting. Additionally, comparisons were drawn with painters who produced similar works, providing further context for the painting's authentication.

Keywords: authenticity determination, SEM, FTIR, HPLC, dendrochronology, dating, oil painting

Article Info

Research Article

Received: 07/01/2025

Accepted: 15/02/2025

Cite this article as:

Küçük, B., & Emre, G. (2025). Copying and Forgery in Oil Paintings: Researching and Application Example of Identification of Authenticity by Scientific Analysis. *Anasay*, 31, 80-106.

[1] This article is derived from a section of the master's thesis titled “Copying and Forgery in Oil Paintings: Researching and Application Example of Identification of Authenticity by Scientific Analysis”.

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Öz

Bu çalışmada, İstanbul Üniversitesi Edebiyat Fakültesi koleksiyonuna ait, ressamı ve tarihi bilinmeyen, bir yüzeyinde manzara diğer yüzeyinde ise nü kadın portresi bulunan imzasız bir yağlı boya tablonun tarihlendirilmesi ve özgünlük tespiti yapılmıştır. Tablonun her iki yüzeyinin incelenmesinde görünür ışık (VIS), eğimli ışık (RAK), morötesi (UV) ve kızılötesi (IR) ışık kaynakları kullanılarak görsel incelemeleri yapılmıştır. Organik ve inorganik pigment analizleri için Yüksek Performanslı Sıvı Kromatografisi (HPLC) ve Taramalı Elektron Mikroskobu-Enerji dağılımlı X-ışını spektroskopisi (SEM-EDX), bağlayıcı ve astar tabakası analizi için Fourier Dönüşümlü Kızılötesi Spektroskopisi (FTIR), lif analizi için stereo mikroskoptan yararlanılmıştır. Ayrıca dendrokronoloji analizi ile de tablonun şasesinin ahşap türü ve yaş tayini gerçekleştirilmiştir. Sanat tarihi araştırmaları ile sanatçısı ve yılı bilinmeyen tabloda üslup, ressamın kullandığı teknik ve kurguladığı kompozisyonun sanatsal özellikleri incelenmiştir. Pigment araştırmaları kapsamında yapılan HPLC analizleri, tabloda organik pigment olmadığını ortaya koymuştur ve SEM-EDX analizleri ile ultramarin, kadmiyum kırmızı, manganez oksit, guignet yeşili, kurşun kırmızısı (minium), sülyen, çinko beyazı, kurşun beyazı, Verona yeşili, fildişi/kemik siyahı, litopon, molibdat kırmızı, permanent beyazı, Prusya mavisi, Brunswick yeşili, zirkonyum oksit ve siyah demir oksit tespit edilmiştir. FTIR analizleri ile de tabloda kullanılan boyalarının bağlayıcısının bezir yağı olduğu anlaşılmıştır. Mikroskop ile yapılan lif analizinde tuvalin keten olduğu saptanmıştır. Şase üzerinde yapılan dendrokronoloji analizlerinde ise 1913 tarihine ulaşılmış ancak işlenmiş odunun tarihlemesinin yapılamayacağı belirtilmiştir. Tüm analiz sonuçları değerlendirilerek tablo için yaklaşık tarihleme yapılmış ve ayrıca benzer eserler veren ressamların resimleri karşılaştırmak için çalışma kapsamında sunulmuştur.

Anahtar Kelimeler: *özgünlük tespiti, SEM, FTIR, HPLC, dendrokronoloji, tarihlendirme, yağlı boya tablo*

Araştırma Makalesi

Geliş Tarihi:07/01/2025

Kabul Tarihi:15/02/2025

Atıf

Küçük, B., & Emre, G. (2025). Yağlıboya Tablolarda Kopya ve Sahtecilik: Bilimsel Analizlerle Özgünlük Tespitinin Araştırılması ve Uygulama Örneği. *Anasay*, 31, 80-106.

Introduction

Establishing the authenticity of works of art is crucial for the protection of both the art world and cultural heritage. This process is meticulously carried out by art experts to prevent forgery and determine the true value of artworks. A number of methods and analyses are used to determine authenticity. These include provenance research, art historical research, visual examinations and research using analytical methods.

Origin-Property searches are, in general terms, the collection, compilation and research of all information about a work of art to determine its accuracy. For example, references such as signature, address, artist, name of the person or persons related to the sale of the work, date, seal information on the work of art are important. In addition, the measurements of the work, documentation of its current condition, research on restoration period, literature sources in which the work is subjected or mentioned, accessible invoices for its sale, and information about its exhibition history or exhibition catalogs, detailed complete catalogues (Catalogues Raisonnés) if the artist is known, also provide important information about the history of ownership (Flescher, 2020, p. 42; IFAR, 2024; Stolberg & Lehmann, 2020, p. 58; Karrels, 2017). This information also covers art history research and allows access to information about the importance of the work in terms of art history. In addition, while art historical studies evaluate features such as the subject, composition elements, period, style and school of a painting, they also include research such as the artist, if known, the importance of the painting, and comparison with other examples. From the 18th century onwards, it has been argued that the criteria for evaluating a painting should move from the general to the detailed and that many questions can be answered in the details. While general evaluations include intuition, composition, figures, subject selection, color-shadow, perspective, anatomy, detailed evaluations include the examination of drawings such as portraits, legs, arms, movements, hands, feet, ears and noses. Varlık Şentürk, on the other hand, in his book "Analytical Painting Analyses", called the examinations such as the name of the artist,

the name of the painting, the subject, and the technique as iconographic examinations. Iconography can be defined as the identification and determination of the images seen by the eye in works of art (Varlık Şentürk, 2012, p. 19; Gümüş, 2023, p. 3751; Turan, 2020, p. 3868).

Visual inspections involve examining the surfaces and substrates of paintings using a variety of different wavelengths of light sources. The human eye can detect light with wavelengths in the range of 400-700 nanometers (nm). This range is called visible light (VIS). Light with wavelengths below 400 nm is called ultraviolet (UV) light, and light above 700 nm is called infrared (IR) light. All wavelengths can pass through different layers of the paintings and create various radiations, allowing us to gather information about the work. For example, while details seen on the surface of the painting (signatures, distortions, brush strokes, and surface dirt) can be examined with visible light, details invisible to the naked eye can be revealed with UV light, thanks to the penetration of the light wavelength into the lower layers of the painting. In addition, different radiations occurring in the varnish can help distinguish between old and new varnish. With infrared examinations, the artist's sketches and hidden signatures can be revealed (Çağlar, Eryurt, 2017, p. 32; Yöndem, 2018, p. 107; Bilici Genç et al., 2021, p. 673). High-resolution photography, 3D scanning methods, or gigapixel photography also provide information about the surface.

Analytical, or in other words, scientific analyses provide information such as organic and inorganic pigment content, binder analysis, and age determination of wooden elements. They offer important insights for dating the artifact by illuminating the production process. Multispectral examinations, hyperspectral examinations, radiographic examinations (X-ray Radiography, X-Ray Fluorescence, X-Ray Diffractometry), mass spectroscopy (Laser Etching Inductively Coupled Plasma Mass Spectrometry, Multiple Collector-Inductively Coupled Plasma Mass Spectrometry, Pyrolysis Gas Chromatography-Mass Spectrometry), chromatographic investigations (High Performance Liquid Chromatography), spectroscopic investigations (Raman spectroscopy, Fiber optic reflectance spectroscopy, Fourier transform infrared spectroscopy), dendrochronology, and various analytical methods such as Carbon 14 and SEM-EDX can directly answer questions about the content of the painting. The most important criterion in the selection of analytical methods is that they are non-destructive. However, the cost, applicability, and accessibility of the selected analysis are also important factors (Schenatto et al., 2022, p. 1; Janssens et al., 2016, p. 5).

Research on the authenticity of works of art requires the cooperation of different disciplines such as chemistry, biology, art history and conservation. This interdisciplinary work is an important example for the proper evaluation of works of art. All these researches and investigations are of great importance to prevent forgery of artworks, to pass on cultural heritage to future generations and to create reliable collections.

The work that constitutes the subject of the study is an unsigned oil painting on canvas, with paintings on both sides, belonging to the Collection of Istanbul University, Faculty of Letters. There is a landscape painting on the front surface of the painting and a nude figure on the back surface. The dimensions of the painting are 81.5 x 61 cm. It was learned that the painting, which has no date on it, was added to the university's collection between 2003-2004. However, there is no further information about its history.

The aim of this study is to present the results of an interdisciplinary study using art historical research, visual analysis and scientific analysis methods. Thus, it is to determine the authenticity and approximate dating of the painting in question.

There are paintings with different subjects on both sides of the painting, which is the subject of the study, and it is aimed to eliminate confusion by naming these paintings as “landscape surface” and “nude figure surface”.

1. ART HISTORY STUDIES

Landscape Surface

The exhibited surface of the painting is a landscape, and the compositional elements are two mosques in a row, the sea view in front of the mosques, the ferry pier and a few vague architectural structures on the opposite shore. The fact that the roofs of the houses in the foreground are visible and all the architectural features of the mosques are fully depicted gives the impression that the artist painted the painting from a high vantage point. The green trees, vivid colors and clear sky suggest that the painting was painted in spring or summer (Image 1).

Image 1: The landscape front surface of the painting, Istanbul University Faculty of Letters Collection (Photograph: Betül Küçük)

In the painting, it is seen that yellow, blue, green and black colors are used along with orange tones. When the tree on the right side of the painting and the bird figure on the roof, which forms the foreground of the painting, are examined, it is observed that the artist made wide brush strokes with comfortable movements while painting (Image 2). In addition, looking at the painting in general, the artist went out into nature and transferred what he saw to the canvas or wanted to give this impression. However, he/she deformed compositional elements such as mosques, trees and houses and reflected them on the canvas.

Image 2: Landscape side- Bird figure (Photograph: Betül Küçük)

When viewed from a wider angle, the scene is thought to depict a view from Üsküdar towards Beşiktaş. The mosque closest to the viewer is believed to be the Valide-i Cedid Mosque, also known as the Yeni Valide Mosque or Gülnuş Valide Sultan Mosque, built between 1708 and 1711. The second mosque, visible between the minarets of this mosque, is thought to be the Mihrimah Sultan Mosque, built by Mimar Sinan in 1548. Due to the painter's perspective, the minaret of the Valide-i Cedid Mosque on the left side obscures one of the minarets of the Mihrimah Sultan Mosque (Image 3). The location of the ferry on the shore is thought to be the first public Üsküdar pier, built in 1852 (Image 4).

Image 3: The area thought to be the Valide-i Cedid Mosque. (Photograph: Betül Küçük)

Image 4: The area thought to be Üsküdar Pier (Photograph: Betül Küçük)

When the compositional elements on the opposite shore are examined, a round building and another longitudinal rectangular architectural element can be seen on the left side of this building. It is thought that the round building may be the Büyük Mecidiye Mosque, also known as Ortaköy Mosque, which was built in 1853. The White-colored long rectangular building to the left of the mosque and away from the mosque on the seashore is estimated to be Kabataş High School, which was established in 1908 under the name "Kabataş Mekteb-i Idâdisi". The green area behind Kabataş High School is thought to be the Yıldız Grove or Yıldız Park (Image 5).

Image 5: Composition elements on the front side of the painting on the landscape surface (Drawing: Betül Küçük)

When comparing the photograph of Üsküdar from the 1960s on the right with the landscape surface of the painting of unknown date on the left in Image 6, several similarities stand out. The positioning of the ferry pier in the photograph and its distance from the Mihrimah Sultan Mosque appear consistent. The dimensions and length of the building on the opposite pier, which is

thought to be Kabataş High School, align with the proportions of the building in the painting. Additionally, the depiction of the area believed to be Yıldız Grove or Yıldız Park seems quite consistent with the photograph.

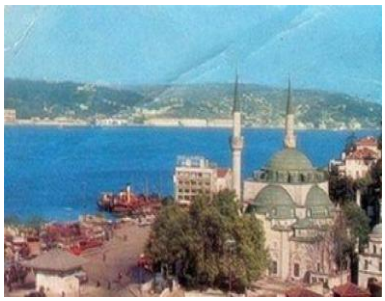
a  b 

Image 6: a) The surface on which the painter worked on the subject of landscape (Photograph: Betül Küçük**),** b) Üsküdar photograph from 1960 (https://archives.saltresearch.org/handle/123456789/97603)

Another important point that draws attention in the painting is that the artist does not see the Bosphorus Bridge in the painting drawn from the angle he is looking at. The fact that there is nothing about the bridge suggests that the bridge has not yet been built. However, this is only an assumption. There is also the possibility that the artist may have made use of an old photograph or postcard while making his painting or that he may have interpreted what he saw differently.

Nude Figure Surface

On the back surface of the painting with the nude subject, the figure is depicted sitting on a stool with a cloth on it. While the figure's legs and kneecaps point to the right side in terms of direction (according to the way the figure sits), her torso points to the left side, giving a contrast. The left arm is behind the body and presses against the stool for balance. The right arm is not visible. The head is turned to the left and the neck is almost invisible. It is seen that the figure has a red accessory in her hair. In the background of the painting, vaguely human figures are depicted in a small boat in a wooded area. It is thought that this may be the painter's way of explaining that he painted the figure in nature (Image 7).

Image 7: The back surface and details of the painting with the nude woman figure (Photograph and drawing: Betül Küçük)

The first painted part of the painting should be the nude figure. The reason for this idea is that the areas of the canvas stretched on the frame are painted inside the frame pockets. If the landscape painting was painted first and then the nude painting was added by turning the canvas around, the areas under the frame should not have been painted. However, the fact that these areas are completely painted indicates that the nude figure was painted first. It is thought that the

landscape painting may have been added later by removing the canvas from the frame for financial or other reasons and re-stretching the unpainted surface back onto the frame. On the back surface where the nude figure was painted, it is observed that the excess canvas cloth was not cut off after it was stretched on the frame. This situation suggests that there was no aesthetic concern.

Looking at the painting in general, the figure's head is drawn smaller than its body, indicating a proportion issue. The composition is leaning to the right from our point of view. It is thought that the red-burgundy colored fabric or cover in the lower left corner of the painting was added to reduce the tonal coldness of the painting. There are also contours surrounding the composition elements in many parts of the painting. The painter must have used too much thinner in the paints, as there are unsaturated painted areas on the canvas. The artist's style is closer to the Constructivism approach in art history. In Constructivism, also known as non-figurative or constructive painting, the artist has moved from seeing painting as an imitation of nature to seeing it as shaped by its own colors, lines, and expression. In the constructivist understanding, artists were divided into two groups. In one group, the painter transfers his painting to the canvas using geometric forms, while in the other, color and form elements come to the fore (Şerbetçi, 2008, p. 33).

2. EXPERİMENTAL

Visual Examinations

Visible light (VIS) and raking light (RAK) examinations

Macro and micro shots were taken with a CANON EOS 600D semi-professional camera and 18-55mm/Macro 0.25m/0.8 ft lens. The photographs were saved as JPEG. ADOBE PHOTOSHOP 2021 program was used for editing the photographs.

Examination with ultraviolet light (UV)

Fabrizio 110V-220V 2A max ultraviolet light source was used as ultraviolet light (UV) source. Peca #916 IR-UV Camera 67 mm filter was used for UV absorption. Photographs were taken with a CANON EOS 600D semi-professional camera and 18-55mm/Macro 0.25m/0.8 ft lens and images were saved in JPEG format. Shooting times were very short to prevent UV light from damaging the painting.

Examination with infrared light (IR)

Two halogen lights were used as infrared light (IR) sources. Peca brand filters with different wavelengths were used for IR absorption. These filters; Peca #900 (18A), Peca #902 (70), Peca #910 (87C), Peca #914 (89B), Fujifilm digital camera with NIKON AF-100 lens with UV and IR sensitivity between 380-1000 nm. Considering the effects of IR light on the painting, the shooting times were realized in a very short period of time in order not to damage the painting.

Optical reviews

The fiber sample taken from the edge of the canvas was examined to determine its type. Fisher Scientific Micromaster Microscope was used to obtain large images and OLYMPUS brand SZ-PT Stereo Microscope was used to obtain the fiber view.

Analytical Methods

HPLC-DAD Analysis

Agilent Technologies brand HPLC-DAD / 1200 Series / G1311A- G1322A- G1311A-G1329A- G1316A- G1315D device was used. Eleven samples from the landscape surface and 8 samples from the nude figure composition were taken and analyzed by HPLC-DAD. Samples were taken at a micro scale and carefully from areas where the paint layer was flaking off.

SEM-EDX Analysis

Tescan brand SEM-EDX VEGA 3SB4- Easy Pobe / XFlash Detector 410M was used. The coating device and pump were Quorum EMS 150R ES- Q150R- AC1PH-MTR. 11 samples were taken from the surface depicting the landscape, 8 samples were taken from the surface featuring the nude figure, and 2 samples were taken from the primer layer. Samples were taken at a micro scale and carefully from areas where the paint layer was flaking off.

FTIR-ATR Analysis

A Perkin Elmer Spectrum 100 FTIR Spectrometer, which contains a Class II/2 Helium Neon Laser with a wavelength of 633 nm, emitting visible continuous wave radiation with a maximum output power of 1 mW, was used. The aim of the FTIR analysis is to identify the binders used in the painting. Four samples were taken from the area depicting the landscape and two samples were taken from the area featuring the nude figure. Additionally, FTIR-ATR analyses were performed on the fiber sample taken from the canvas and the primer layer**.** Samples were taken at a micro scale and carefully from areas where the paint layer was flaking off.

Dendrochronology

A total of 2 samples were taken from the frame of the artwork to determine the age and type of the wood.

3. RESULTS AND DISCUSSION

Visual Examinations

In the examinations made with visible light (VIS) and raking light (RAK) on the surface of the landscape and nude figure, the dust and dirt layer on the surface of the painting can be seen quite clearly. Additionally, the paint layer and the damages on the canvas were detected in more detail in the examinations made with these lights. It was observed that there is a layer of primer on both sides of the painting. On the surface of the painting with the nude figure, there is a rope attached to a metal bracket for hanging the frame on the wall. In addition, a pencil inscription on the frame, which is not fully legible, was found on this surface (Image 8).

Image 8: Stretcher details (Photograph: Betül Küçük)

Both surfaces were examined with ultraviolet light (UV) for the presence of a signature that could not be detected with visible light (VIS), but no signature or signature residue was found. In addition, retouching and varnish were not detected. In the examination made on the surface with the subject of nude figure, 2 human figures in a tree and a boat drawn by the artist on the left side of the painting can be seen more clearly in the examinations made with ultraviolet light.

In the examinations made with infrared light (IR), it was examined whether there was a sketch / draft drawing. However, no evidence of the artist's sketching was found on either surface. In this case, it was understood that the artist did not need a preparatory drawing and applied the oil paint directly on the canvas (Image 9).

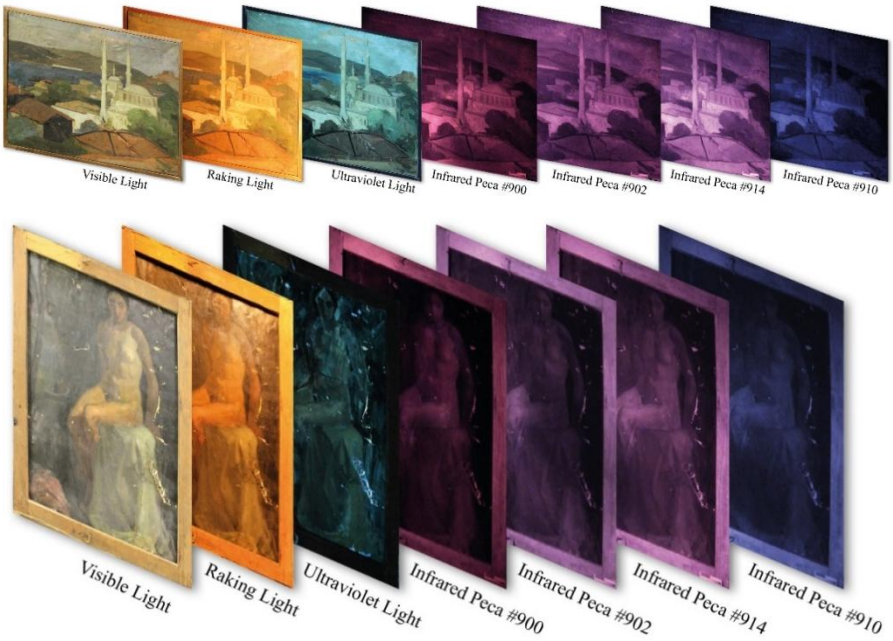


Image 9: Visual examinations made on landscapes and nude figure surfaces (Photograph: Betül Küçük)

Analytical Methods

Pigment and Binder Analysis of the Landscape

The areas where 11 micro-scale samples were taken from the landscape surface of the painting and the numbering and naming of these samples are as given in the image below. Sample number 1 is named "Blue" and was taken from the sea area of the painting. Sample number 2 is labeled "Brown-Orange" and was taken from the roof of the house. Sample number 3 is labeled "White-Yellow" and is taken from the mosque building. Sample number 4 is labeled "Green-Dark". Since samples were taken from light and dark color areas in the table, the naming was done accordingly. The Green-Dark sample was taken from the green area on the opposite shore. Sample number 5 was named "Blue Sky" and was taken from the blue tones of the sky area as indicated in the visual. Sample number 6 is named "Black-Green" and is taken from the area where the house is depicted. Sample number 7 is named "Black". It was noteworthy that the artist used different shades of black color while coloring the house elements, and for this reason, it was decided to take samples from these areas and investigate whether they have the same pigment content. Sample number 8 was named "Green Medium Tone", sample number 9 was named "Light Green" and it was decided to take samples from different areas in order to determine the content of the different color tones used by the artist as in the house depictions. Sample number 10 was named "Orange" and was taken from the roof of the house, which is closest to the audience in the composition. Finally, sample number 11 was named "Beige" and was taken from the cloud motif in the sky (Image 10) (Table 1). The naming and numbering of the samples were used in the same way throughout the entire analysis process.

Image 10: Places sampled from the landscape surface of the painting (Photograph and drawing: Betül Küçük)

Sample No	Sample Name
1	Blue
2	Brown
3	White
4	Dark Green
5	Blue Sky
6	Black-Green
7	Black
8	Medium-Tone Green
9	Light Green
10	Orange
11	Beige

Table 1: Identification of samples taken from the landscape surface

SEM-EDX Analysis

HPLC analyses were performed to examine the organic pigments in the content of the dyes used in the painting, but no organic pigments were found. Therefore, inorganic pigment investigations were needed. An SEM device calibrated with EDX was used for inorganic pigment analysis. The numbering of 11 samples on the landscape surface (Table 1) and their elemental contents according to SEM-EDX analysis results are shown in Table 2.

S. No	C	O	Na	Mg	Al	Si	S	Ca	Zn	Ba	Pb	Cd	Cr	Fe	F	Mo	K	P	Cl	Br	W	Ta	Ir	Sb	Ti
1	42,28	22,96	1,11	0,77	0,94	1,58	3,32	1,87	11,55	6,37	7,25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2	53,40	25,63	0,70	0,61	-	-	0,91	0,40	13,18	-	4,12	1,05	-	-	-	-	-	-	-	-	-	-	-	-	-
3	28,99	21,84	-	-	-	-	2,24	-	21,28	5,93	19,72	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	43,74	24,80	-	0,37	0,30	0,75	1,80	1,24	12,84	3,90	5,82	-	2,16	2,28	-	-	-	-	-	-	-	-	-	-	-
5	50,36	20,23	-	-	-	-	-	-	28,73	-	-	-	-	-	0,68	-	-	-	-	-	-	-	-	-	-
6	45,20	22,84	-	-	-	-	-	0,92	11,85	4,09	11,34	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7	34,53	25,42	1,79	0,16	0,59	1,64	2,68	3,28	7,71	6,93	14,19	-	-	-	-	-	0,22	0,84	-	-	-	-	-	-	-
8	38,14	30,98	1,87	0,67	1,13	0,92	2,51	3,39	8,96	5,45	5,57	-	-	-	-	-	-	0,21	0,20	-	-	-	-	-	-
9	50,52	23,51	0,52	0,35	0,24	-	1,27	-	13,29	3,14	7,16	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10	41,28	19,85	-	-	-	-	3,07	-	14,12	6,62	14,43	-	-	-	-	-	-	-	-	0,64	-	-	-	-	-
11	25,56	20,68	-	-	-	-	-	-	20,28	8,81	19,19	-	-	-	-	5,43	-	-	-	-	0,05	-	-	-	-

Table 2: Element distributions according to SEM-EDX analysis results, Landscape surface

(1) Sample (Blue)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 42.28%), Oxygen (O, 22.96%), Sodium (Na, 1.11%), Magnesium (Mg, 0.77%), Aluminum (Al, 0.94%), Silicon (Si, 1.58%), Sulfur (S, 3.32%), Calcium (Ca, 1.87%), Zinc (Zn, 11.55%), Barium (Ba, 6.37%), and Lead (Pb, 7.25%). According to the analysis results, sample (1) is identified as Ultramarine (Na8-10.Al6.Si6O24S2-4).

(2) Sample (Brown)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 53.40%), Oxygen (O, 25.63%), Sodium (Na, 0.70%), Magnesium (Mg, 0.61%), Sulfur (S, 0.91%), Calcium (Ca, 0.40%), Zinc (Zn, 13.18%), Lead (Pb, 4.12%), and Cadmium (Cd, 1.05%). According to the analysis results, the brown-orange sample is identified as Cadmium Red (CdS+CdSe).

(3) Sample (White)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 28.99%), Oxygen (O, 21.84%), Sulfur (S, 2.24%), Zinc (Zn, 21.28%), Barium (Ba, 5.93%), and Lead (Pb, 19.72%). According to the analysis results, the white-yellow sample is identified as Lead White (2PbCO3.Pb(OH)2) and Permanent/ Barium White (BaSO4).

(4) Sample (Dark Green)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 43.74%), Oxygen (O, 24.80%), Magnesium (Mg, 0.37%), Aluminum (Al, 0.30%), Silicon (Si, 0.75%), Sulfur (S, 0.80%), Calcium (Ca, 1.24%), Zinc (Zn, 12.84%), Barium (Ba, 3.90%), Lead (Pb, 5.82%), Chromium (Cr, 2.16%), and Iron (Fe, 2.28%). According to the analysis results, the dark green sample is identified as Guignet Green (Cr2O3.nH2O + H3BO3).

(5) Sample (Blue Sky)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 43.74%), Oxygen (O, 24.80%), Magnesium (Mg, 0.37%), Aluminum (Al, 0.30%), Silicon (Si, 0.75%), Sulfur (S, 0.80%), Calcium (Ca, 1.24%), Zinc (Zn, 12.84%), Barium (Ba, 3.90%), Lead (Pb, 5.82%), Chromium (Cr, 2.16%), and Iron (Fe, 2.28%). According to the analysis results, the dark green sample is identified as Guignet Green (Cr2O3.nH2O + H3BO3).

(6) Sample (Black-Green)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 45.20%), Oxygen (O, 22.84%), Calcium (Ca, 0.92%), Zinc (Zn, 11.85%), Barium (Ba, 4.09%), and Lead (Pb, 11.34%). According to the analysis results, the black-green sample is identified as Manganese Oxide (MnO.Mn2O3).

(7) Sample (Black)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 34.53%), Oxygen (O, 25.42%), Sodium (Na, 1.79%), Magnesium (Mg, 0.16%), Aluminum (Al, 0.59%), Silicon (Si, 1.64%), Sulfur (S, 2.68%), Calcium (Ca, 3.28%), Zinc (Zn, 7.71%), Barium (Ba, 6.93%), Lead (Pb, 14.19%), Potassium (K, 0.22%), and Phosphorus (P, 0.84%). According to the analysis results, the black sample is identified as Ivory Black (Bone Black) (C + Ca3(PO4)2).

(8) Sample (Medium-Tone Green)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 38.14%), Oxygen (O, 30.98%), Sodium (Na, 1.87%), Magnesium (Mg, 0.67%), Aluminum (Al, 1.13%), Silicon (Si, 0.92%), Sulfur (S, 2.51%), Calcium (Ca, 3.39%), Zinc (Zn, 8.96%), Barium (Ba, 5.45%), Lead (Pb, 5.57%), Phosphorus (P, 0.21%), and Chlorine (Cl, 0.20%). According to the

analysis results, the medium-tone green sample is identified as Green Earth/Verona Green (Fe-Mg-Al-K-hydrosilicate).

(9) Sample (Light Green)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 50.52%), Oxygen (O, 23.51%), Sodium (Na, 0.52%), Magnesium (Mg, 0.35%), Aluminum (Al, 0.24%), Sulfur (S, 1.27%), Zinc (Zn, 13.29%), Barium (Ba, 3.14%), and Lead (Pb, 7.16%). According to the analysis results, the light green sample is identified as Green Earth/Verona Green (Fe-Mg-Al-K-hydrosilicate).

(10) Sample (Orange)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 41.28%), Oxygen (O, 19.85%), Sulfur (S, 3.07%), Zinc (Zn, 14.12%), Barium (Ba, 6.62%), Lead (Pb, 14.43%), and Bromine (Br, 0.64%). According to the analysis results, the orange sample is identified as Lithopone (ZnO + BaSO4) and Lead Red (Minium) = Red Lead (Pb3O4). It is understood that the painter mixed Lead Red with Lithopone to achieve the orange color.

(11) Sample (Beige)

As seen in Table 2, the paint sample taken from this point contains Carbon (C, 25.56%), Oxygen (O, 20.68%), Zinc (Zn, 20.28%), Barium (Ba, 8.81%), Lead (Pb, 19.19%), Molybdenum (Mo, 5.43%), and Tungsten or Wolfram (0.05). According to the analysis results, the beige sample is identified as Lead White (2PbCO3.Pb(OH)2), Molybdate Orange (7PbCrO4.2PbSO4.PbMoO4), and Zinc White (ZnO). It is understood that the painter achieved the desired color by mixing Lead White, Molybdate Orange, and Zinc White.

The mapping of the paint samples taken from the area depicting the landscape, along with the pigments and their formulas, is shown in Table 3 based on the analysis results.

LANDSCAPE

Sample No	Sample Name	Analysis Result	Chemical Formula
1	Blue	Ultramarine	Na8-10.Al6.Si6O24S2-4
2	Brown	Cadmium Red	CdS+CdSe
3	White	Lead White - Permanent White	2PbCO3.Pb(OH)2 - BaSO4
4	Dark Green	Guignet Green	Cr2O3.nH20+H3BO3
5	Blue Sky	Zinc White - Ultramarine	ZnO - Na8-10.Al6.Si6O24S2-4
6	Black - Green	Manganese Oxide	MnO.Mn2O3
7	Black	Ivory Black (Bone Black)	C+Ca3(PO4)2
8	Medium - Tone Green	Verona Green	Fe-Mg-Al-K-hydrosilicate
9	Light Green	Verona Green	Fe-Mg-Al-K-hydrosilicate
10	Orange	Litopon - Lead Red (Minium)	ZnO+BaSO4 - Pb3O4
11	Beige	Lead White - Molybdate Red Zinc White	2PbCO3.Pb(OH)2 - 7PbCrO4.2PbSO4.PbMoO4 - ZnO

Table 3: Pigments and their formulas obtained according to SEM-EDX analysis results

Binder Analysis with FTIR-ATR

For the analysis of binders used in the painting, the FTIR-ATR device was utilized. Examinations were conducted on the samples numbered 1, 4, 9, and 10 on the landscape surface. Care was taken to select samples with the same colors used on both surfaces of the painting. The peaks obtained from the binder analyses are shown in Table 4. The analyses determined that the binder used is linseed oil.

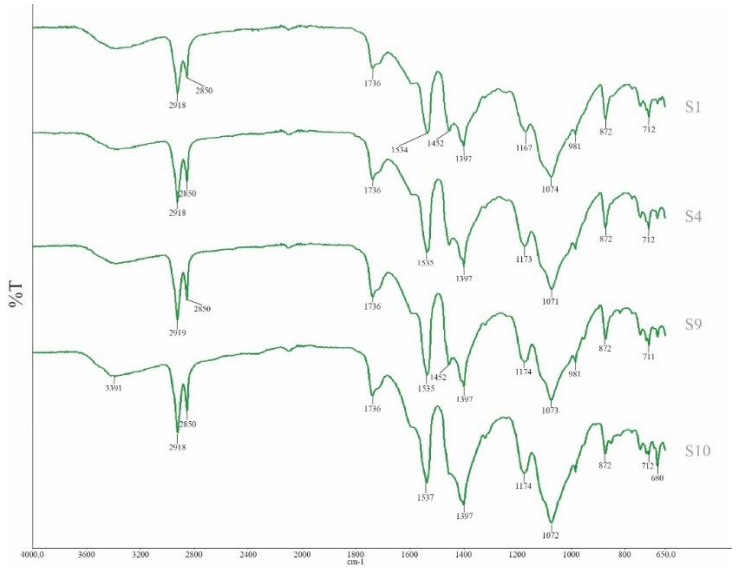


Table 4: FTIR-ATR analysis results (Landscape surface)

Pigment and Binder Analysis of the Nude Figure

The areas from which the 8 micro samples were taken from the surface depicting the nude figure and the numbering and naming of these samples are shown in the image below. Sample number 12 is named "Brown" and was taken from the arm area of the figure. Sample number 13, named "Black," was taken from the background. Sample number 14, named "Green," was taken from the fabric on which the figure is seated.

Sample number 15, named "Light Flesh Tone," was taken from the leg area of the figure. Sample number 16, named "Pink," was taken from the fabric area located in the lower left corner of the painting from our perspective. Sample number 17, named "Tree Motif Brown," was taken from the tree trunk depicted by the artist in the background. Sample number 18, named "Blue," was taken from a dark blue area near the upper left corner of the painting. Finally, sample number 19, named "Light Green," was taken from the light-toned green fabric on which the figure is seated (Image 11). The naming and numbering of the samples have been used consistently throughout the entire analysis process.

Image 11: Locations of samples taken from each surface depicting the nude figure (Photograph and drawing: Betül Küçük)

Sample No	Sample Name
12	Brown
13	Black
14	Green Green
15	Light Skin Tone
16	Pink
17	Tree Motif Brown
18	Blue
19	Light Green

Table 5: Identification of samples taken from the surface depicting the nude figure

SEM-EDX Analysis

HPLC analyses were also performed on the surface depicting the nude figure to examine organic pigments, but no organic pigments were found. Therefore, inorganic pigment investigations were needed. An SEM device calibrated with EDX was used for inorganic pigment analysis (Table 6).

S. No	C	O	Na	Mg	Al	Si	S	Ca	Zn	Ba	Pb	Cd	Cr	Fe	F	Mo	K	P	Cl	Br	W	Ta	Ir	Sb	Ti
12	41,28	23,23	0,33	0,65	0,76	0,98	1,38	5,09	15,30	3,61	5,51	-	-	1,90	-	-	-	-	-	-	-	-	-	-	-
13	55,48	24,51	0,14	0,17	0,50	1,39	1,55	1,37	4,32	3,24	2,70	-	-	4,51	-	-	-	0,11	-	-	-	-	-	-	-
14	68,62	25,08	0,35	0,29	-	0,37	0,42	0,55	2,97	-	-	-	-	-	1,04	-	-	-	0,31	-	-	-	-	-	-
15	65,16	28,65	-	0,32	0,30	-	0,29	0,26	3,07	-	-	-	-	-	1,32	-	-	-	-	-	-	0,62	-	-	-
16	50,24	26,50	-	-	0,42	0,67	0,41	1,11	18,49	-	-	-	-	2,00	-	-	-	0,16	-	-	-	-	-	-	-
17	54,98	26,82	0,26	-	2,29	2,90	2,46	0,50	4,28	5,32	-	-	-	-	-	-	-	-	-	-	-	-	0,18	-	-
18	46,89	21,03	-	-	0,05	0,26	0,53	1,43	29,56	-	-	-	-	-	0,24	-	-	-	-	-	-	-	-	-	-
19	43,46	22,10	0,70	-	0,01	-	1,04	6,20	20,63	1,74	1,69	-	-	1,54	-	-	-	-	-	-	-	0,02	-	0,87	-
20																									
21	46,96	18,58	-	-	0,12	-	-	1,18	13,32	4,63	10,97	-	-	-	-	3,05	-	-	-	-	-	-	-	-	1,18

Table 6: Element distributions according to SEM-EDX analysis results, Surface of the nude figure

(12) Sample (Brown)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 41.28%), Oxygen (O, 23.23%), Sodium (Na, 0.33%), Magnesium (Mg, 0.65%), Aluminum (Al, 0.76%), Silicon (Si, 0.98%), Sulfur (S, 1.38%), Calcium (Ca, 5.09%), Zinc (Zn, 15.30%), Barium (Ba, 3.61%), Lead (Pb, 5.51%), and Iron (Fe, 1.90%). According to the analysis results, the brown sample is identified as Molybdate Orange (7PbCrO4.2PbSO4.PbMoO4), Lead White (2PbCO3.Pb(OH)2), Zinc White (ZnO), and Permanent/Barium White (BaSO4). It is understood that the painter mixed Molybdate Orange, Lead White, Zinc White, and Permanent/Barium White to achieve the desired color.

(13) Sample (Black)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 55.48%), Oxygen (O, 24.51%), Sodium (Na, 0.14%), Magnesium (Mg, 0.17%), Aluminum (Al, 0.50%), Silicon (Si, 1.39%), Sulfur (S, 1.55%), Calcium (Ca, 1.37%), Zinc (Zn, 4.32%), Barium (Ba, 3.24%), Lead (Pb, 2.70%), Iron (Fe, 4.51%), and Phosphorus (P, 0.11%). According to the analysis results, the black sample is identified as Black Iron Oxide (FeO.Fe2O3), Ivory Black (Bone Black) (C + Ca3(PO4)2), and Zinc White (ZnO). It is understood that the painter mixed Black Iron Oxide, Ivory Black (Bone Black), and Zinc White to achieve the desired color.

(14) Sample (Green)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 68.62%), Oxygen (O, 25.08%), Sodium (Na, 0.35%), Magnesium (Mg, 0.29%), Silicon (Si, 0.37%), Sulfur (S, 0.42%), Calcium (Ca, 0.55%), Zinc (Zn, 2.97%), Iron (Fe, 1.04%), and Chlorine (Cl, 0.31%). According to the analysis results, the green sample is identified as Brunswick Green (CuCl2 + Cu(OH)2).

(15) Sample (Flesh Tone)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 65.61%), Oxygen (O, 28.65%), Magnesium (Mg, 0.32%), Aluminum (Al, 0.30%), Sulfur (S, 0.29%), Calcium (Ca, 0.26%), Zinc (Zn, 3.07%), Fluorine (F, 1.32%), and Tantalum (Ta, 0.62%). According to the analysis results, the flesh-tone sample is identified as Zinc White (ZnO).

(16) Sample (Pink)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 50.24%), Oxygen (O, 26.50%), Aluminum (Al, 0.42%), Silicon (Si, 0.67%), Sulfur (S, 0.41%), Calcium (Ca, 1.11%), Zinc (Zn, 18.49%), Iron (Fe, 2%), and Phosphorus (P, 0.16%). According to the analysis results, the pink sample is identified as Zirconium Oxide (ZrO2) and Black Iron Oxide (FeO.Fe2O3).

(17) Sample (Brown)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 54.98%), Oxygen (O, 26.82%), Sodium (Na, 0.26%), Aluminum (Al, 2.29%), Silicon (Si, 2.90%), Sulfur (S, 2.46%), Calcium (Ca, 0.50%), Zinc (Zn, 4.28%), Barium (Ba, 5.32%), and Iridium (Ir, 0.18%). According to the analysis results, the brown sample is identified as Lithopone (ZnO + BaSO4).

(18) Sample (Blue)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 46.89%), Oxygen (O, 21.03%), Aluminum (Al, 0.05%), Silicon (Si, 0.26%), Sulfur (S, 0.53%), Calcium (Ca, 1.43%), Zinc (Zn, 29.56%), and Fluorine (F, 0.24%). According to the analysis results, the blue sample is identified as Zinc White (ZnO) and Prussian Blue (Fe4[Fe(CN)6]3). It is understood that the painter mixed Zinc White and Prussian Blue to achieve the desired color.

(19) Sample (Light Green)

As seen in Table 6, the paint sample taken from this point contains Carbon (C, 43.46%), Oxygen (O, 22.10%), Sodium (Na, 0.70%), Aluminum (Al, 0.01%), Sulfur (S, 1.04%), Calcium (Ca, 6.20%), Zinc (Zn, 20.63%), Barium (Ba, 1.74%), Lead (Pb, 1.69%), Iron (Fe, 1.54%), Tantalum (Ta, 0.02%), and Antimony (Sb, 0.87%). According to the analysis results, the light green sample is identified as Green Earth/Verona Green (Fe-Mg-Al-K-hydrosilicate).

The mapping of the paint samples taken from the area depicting the nude figure, along with the identified pigments and their formulas, is shown in Image- 13 and Table -7 based on the analysis results.

NUDE FIGURE

Sample No	Sample Name	Analysis Result	Chemical Formula
12	Brown	Lead White - Molybdate Red Zinc White - Permanent White	2PbCO3.Pb(OH)2 - 7PbCrO4.2PbSO4.PbMoO4 - ZnO - BaSO4
13	Black	Black Iron Oxide - Ivory Black Bone Black - Zinc White	FeO.Fe2O3 - C+Ca3(PO4)2 - ZnO
14	Green	Brunswick Green	CuCl2+Cu(OH)2
15	Light Skin Tone	Zinc White	ZnO
16	Pink	Zirconium Oxide - Black Iron Oxide	ZrO2 - FeO.Fe2O3
17	Tree Motif Brown	Litopon	ZnO+BaSO4
18	Blue	Zinc White - Prussian Blue	ZnO - Fe4[Fe(CN)6]3
19	Light Green	Verona Green	Fe-Mg-Al-K-hydrosilicate
20	Fiber Sample	Linen	
21	Primer Layer	Zinc White - Lead White - Litopon Titanium White	ZnO - 2PbCO3.Pb(OH)2 - ZnO+BaSO4 - TiO2

Table 7: Pigments and their formulas obtained according to SEM-EDX analysis results, surface of nude figure.

The pigments identified on both surfaces of the oil painting studied were examined, along with their usage and commercial production dates:

Ivory/black bone, a carbon-based pigment obtained from charred animal bones, has a usage history dating back to Egyptian, Greek, and Roman art. This pigment has appeared on the palettes of artists such as Johannes Vermeer (1632-1675), Thomas Bardwell (1704-1767), Paul Cezanne (1839-1906), and Picasso (Eastaugh, et al., 2008, p. 90; Fuster-Lopez, et al., 2020, p. 4).

Verona green, described in a 1574 catalog from Verona, Italy as Terre verde di Verone, terra di Verona, Verona green, and Verona earth, has been frequently used since the 17th century and is still sold today as both dry pigment and proprietary mixtures. Modern paint manufacturers such as Winsor & Newton and Van Gogh produce it under the name terre verte.

Permanent white was proposed as an alternative to white in the late 1700s, with synthetic production beginning in the early 1800s. It was known to be used by artists as a filler material or color lightener (Şerifaki & İpekoğlu, 2021, p. 499).

It has been found that Brunswick green was prepared by Johann Heinrich and Christoph Julies in the town of Braunschweig, Germany, and named after this town. After its discovery in 1764, production began in their factories in 1767 (Eastaugh, et al., 2008, p. 70).

Lead red was not widely used among artists until the 19th century. It became known and popular after being found in the painting materials of Joseph Mallord William Turner and in the pigment collection of Swiss painter Arnold Böcklin (Feller, 2012, p. 113).

It has been determined that ultramarine was widely used in Europe in the 14th-15th centuries, and its synthetic production was carried out by Jean Baptiste Guimet (1795-1781) in 1828. Subsequently, factories were established in France, Germany, England, Belgium, Austria, and the USA, leading to its widespread use (Orna, 2013, p. 60; Roy, 2012, p. 56).

Although the first attempts to introduce zinc white as a pigment date back to the 1780s (Feller, 2012, p. 170), it became a widely used pigment by artists in the 1850s. It replaced lead white due to its non-toxic nature and resistance to darkening in the presence of sulfur gases.

Guignet green was first produced in 1838 by French chemist Pannetier and his assistant Binet under the name ‘Viridian’. However, it was a difficult pigment to obtain due to its high price compared to other greens available on the market. In 1859, chemist Guignet managed to produce the same color through cheaper methods. It is known that after obtaining the patent for this color and method, it was named Guignet Green (FitzHugh, 1997, p. 274).

It has been found that lithopone was produced as a substitute for lead white in the 1870s, that manganese oxide was patented in 1871 by Rowan in England, and that its synthetic form appeared on artists' palettes in the 19th century (Eastaugh, et al., 2008, p. 255). However, its natural form was not widely used in oil paints (Spring, et al., 2003, p. 101).

Lead white has been known to be used since ancient times. However, due to its toxicity, its final production was in 1906, and its use was banned in 1970. Despite this, it continues to be used by artists today, which holds greater significance for dating purposes.

It is known that cadmium red, with orange and red tones resulting from the increase of selenium content within calcium sulfide, was first commercially produced in 1910 (Feller, 2012, p. 79).

The information obtained from sources indicates that black iron oxide has been used since after 1920. In the painting examined within the scope of the study, the molybdate red color, which is part of the artist's palette on both surfaces, was discovered by Schultze in 1863, later contributed to by Jaeger & Germs in 1921, and described in a German patent in 1930 (Keijzer, 1990, p. 216). Commercial production of the molybdate red synthetic inorganic pigment, one of the important developments of the 20th century, began in 1936 (Herbst, et al. 2004, p. 3) (Image 19).

Binder analysis with FTIR-ATR

Based on the binder analyses conducted on samples 13 and 14, which are pigments commonly used on both surfaces of the painting taken from the surface depicting the nude figure, it was determined that linseed oil was used as the binder (Table 8).

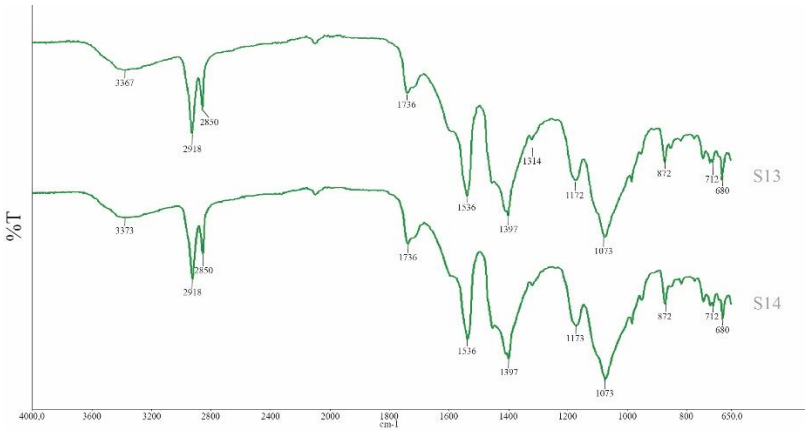


Table 8: FTIR-ATR analysis results, Surface of nude figure

Stretcher Examinations

There is address information written in pencil on the stretcher. However, the writing could not be read under visible light (VIS) examination. The writing area was examined under UV light, revealing the words "Apartmanı ve no/3." However, the rest of the writing could not be read. Subsequently, IR examinations were conducted on the area thought to be written in pencil, revealing "Maçka Teşvikiye Caddesi Zersen/Zerşen Apartmanı No (3)." The obtained images were edited in Adobe Photoshop 2022 and then traced over the writing area on the photo using an Xp-Pen Deco Pro Medium model pressure pen graphics tablet (Image 12-13).

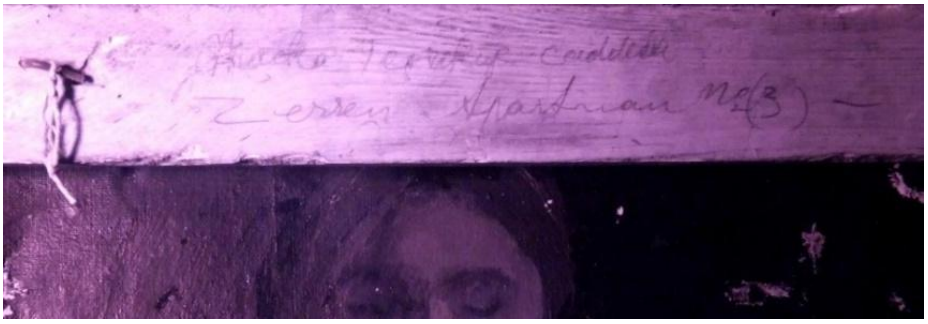


Image 12: Examination of the writing area on the stretcher under infrared light using a Peca#914 (89B) filter (Photograph: Betül Küçük)

Image 13: Deciphering the writing area (Photograph: Betül Küçük)

The other investigation conducted on the stretcher, on which the artist stretched the canvas, was dendrochronological analysis to determine the type of wood used. According to the analysis results, the wood type used is identified as fir. Based on the annual ring analysis graph, the last ring of the examined sample dates to 1913. However, since the wood is processed, precise dating could not be achieved (Image 14-15-16) (Graph1).

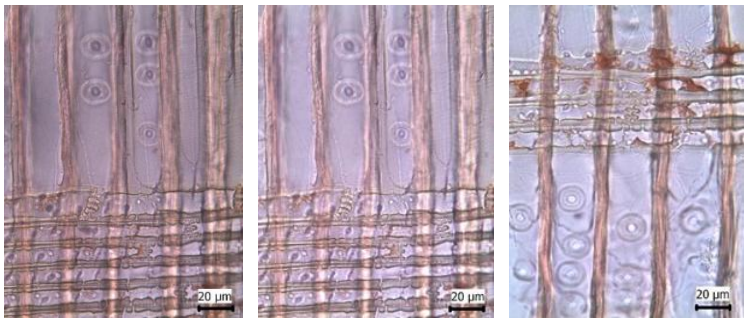


Image 14: Microscopic images of the stretcher sample (Photo: Ünal Akkemik)

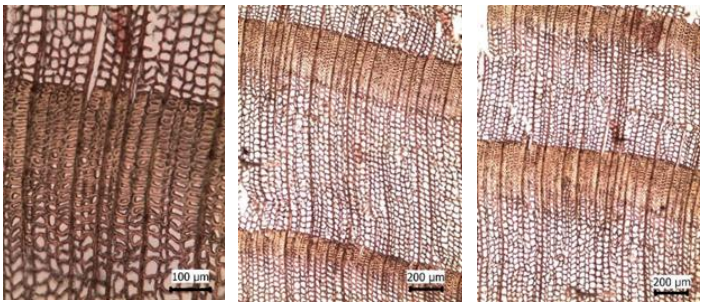


Image 15: Cross-sectional images of the stretcher sample (Photograph: Ünal Akkemik)

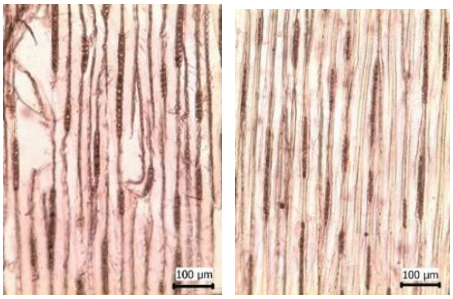
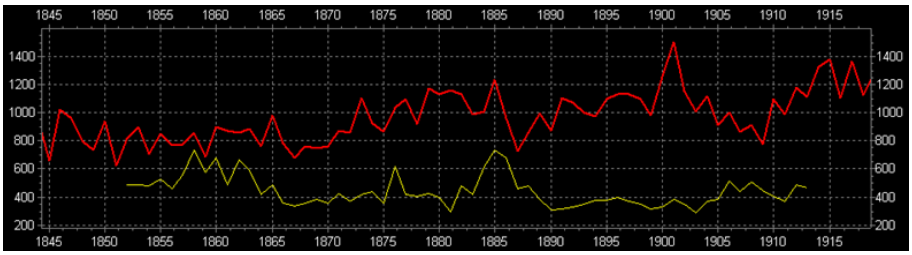


Image 16: Tangential sectional images of the stretcher sample (Photograph: Ünal Akkemik)



Graph 1: Dendrochronological analysis graph (Graphic: Ünal Akkemik)

Ground Layer Examinations

In the analysis of the ground layer, SEM-EDX and FTIR-ATR devices were used in the analysis of the primer layer. While the presence of inorganic pigments in the primer layer was investigated using SEM-EDX, the binder used in the primer layer was determined through FTIR-ATR analyses. In addition, it was determined whether the binder used in the pigments and the binder used in the primer layer were the same.

As seen in Table-9, Carbon (C, 46.96%), Oxygen (O, 18.58%), Aluminum (Al, 0.12%), Calcium (Ca, 1.18%), Zinc (Zn, 13.32%), Barium (Ba, 4.63%), Lead (Pb, 10.97%), Molybdenum (Mo, 3.05%), and Titanium (Ti, 1.18%) were detected in the sample taken from the primer layer at this point. According to the analysis results, the sample taken from the primer layer was identified as Zinc White (ZnO), Lead White (2PbCO3.Pb(OH)2), Lithopone (ZnO + BaSO4), and Titanium White (TiO2) (Table 7).

S. No	C	O	Na	Mg	Al	Si	S	Ca	Zn	Ba	Pb	Cd	Cr	Fe	F	Mo	K	P	Cl	Br	W	Ta	Ir	Sb	Ti
21	46,96	18,58	-	-	0,12	-	-	1,18	13,32	4,63	10,97	-	-	-	-	3,05	-	-	-	-	-	-	-	-	1,18

Table-9: SEM-EDX analysis results of the primer layer.

FTIR-ATR was used to determine the binder used in the primer layer. According to the analysis result, it was determined that the binder used in the primer layer was linseed oil. The FTIR-ATR analysis result of the primer layer is as shown in Table 10.

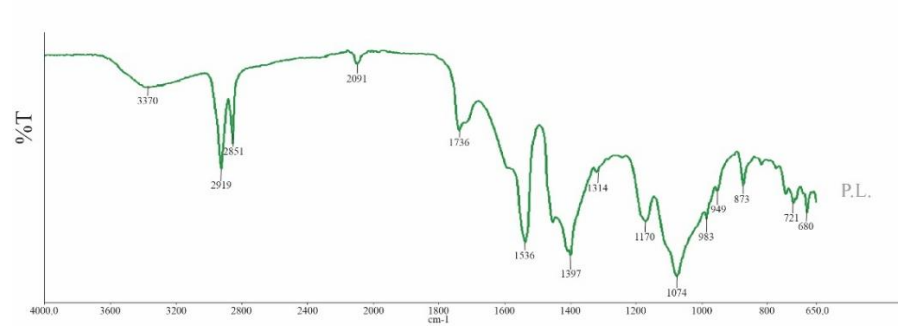


Table 10: FTIR-ATR analysis results of the primer layer.

Fiber Examinations

Woven fabrics used in canvas production are made of animal or plant fibers. Plant fibers include seed fibers such as cotton, stem fibers such as flax, hemp, and jute, as well as leaf and fruit fibers. Animal fibers can be obtained from wool and silk (Yaşayan, 2014, p. 11). Separation and identification of these types are possible by examination under a microscope. Each plant fiber preserves its own characteristic shapes, and these images allow for classification and identification.

According to the results obtained, when the fiber sample taken from the canvas is examined under a microscope, it is seen that the thread gives a relatively long and polygonal image. These characteristic features match with linen (Image 17).

In the examination of the fiber sample, binder analysis was also performed with FTIR-ATR analyses in addition to the microscope, and the pigments, primer layer, and binders in the canvas were determined and compared.

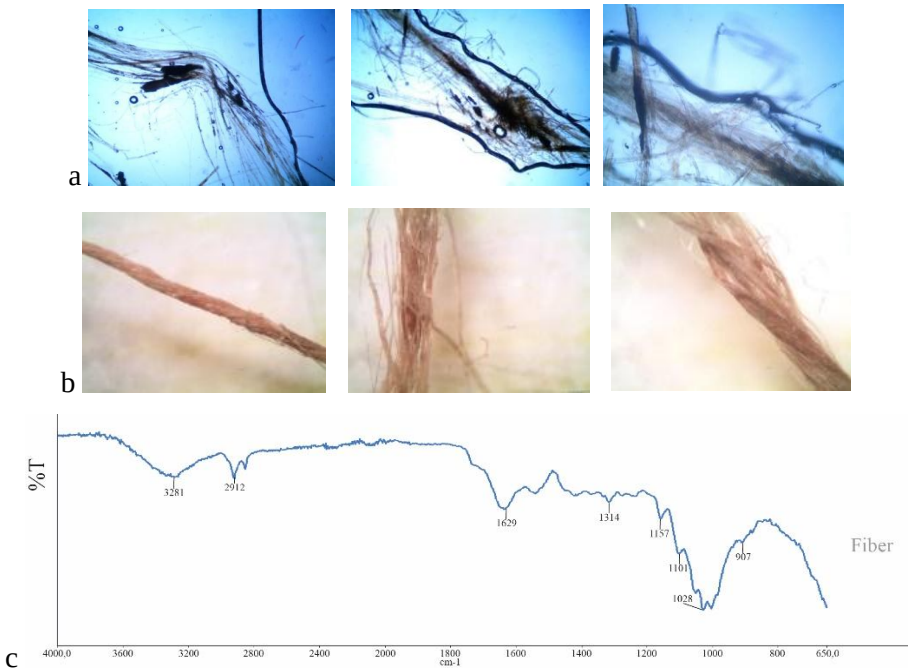


Image 17: Analyses performed on the fiber sample a-b) microscope examinations, c) FTIR-ATR analysis graph (Photograph: Betül Küçük)

CONCLUSIONS

The oil painting on canvas belonging to the Istanbul University Faculty of Letters collection is double-sided. One side of the painting features a landscape, while the other side depicts a nude figure. The dimensions of the painting are 81.5 x 61 cm. There is no information regarding the history of the painting. No artist or date is attributed to the work. The study of the oil painting was conducted under two main headings. The first is art history studies, and the second comprises visual examinations and analytical methods.

As a result of the visual examinations, including visible light (VIS) and raking light (RAK) studies, deformations and paint peelings were observed on the painting. These deteriorations indicate that the painting was kept in unsuitable environmental conditions. Over time, the binder lost its effectiveness, leading to losses in the paint layer. Additionally, the tear observed on the canvas suggests that the painting sustained an impact.

As a result of examinations with ultraviolet (UV) and infrared (IR) light, it was determined that no preliminary sketch was made by the artist, the painting has not undergone restoration and has reached the present day in the state painted by the artist, and there is no varnish layer on the painting.

In the area of the painting depicting the nude figure, the address information on the stretcher became readable through examinations with UV and various IR filters. As a result of these examinations, it was determined that the address on the stretcher is 'Maçka Teşvikiye Caddesi Zersen/Zerşen(?) Apartmanı No (3).' Despite reviewing Pervititch maps and German Blue maps of Teşvikiye, Nişantaşı, and Şişli, no information about Zersen/Zerşen Apartment (?) was found.

There could be various reasons for the address being written on the stretcher. One possibility is that the artwork was commissioned, and the artist wrote the address to which it would be delivered. Another option is that it was created in a painting studio, and the studio's address was written on the stretcher.

According to art history studies, it is thought that the artist intentionally deformed both the landscape and the nude sides of the painting. As a result, it was determined that it was made in a constructivist approach. In the history of art, the artist unions with a constructivist understanding are the Independent Painters and Sculptors Association (1929-1942) and the D Group (1933-1947).

The fact that the painting is double-sided is a significant feature. In the history of painting, it is generally known that artists used their paintings double-sidedly for financial reasons or painted over an existing image to create a new one. Especially when considering the early years of the Republic, it became difficult for artists to obtain painting materials such as brushes, canvases, and paint (Keskin, 2014, p. 92).

The depiction of human figures, such as portraits or nudes, began later in Turkish art history. Due to the Ottoman Empire's religious sensitivities, there were gaps in figurative works, and it took a process for artists to fill these gaps. In the chronology of Turkish art history, it is seen that artists known as the 1914 Generation or the Çallı Generation, after receiving their education abroad, focused more on figurative compositions and themes depicting social life (Keskin, 2014 p. 97).

The figurative approaches of the Independent Painters and Sculptors Association (1929-1942) vary due to the unique works of the artists. Influenced by art movements such as Realism, Expressionism, and Cubism, the artists created diversity. For instance, Mahmut Cüda and Şeref Akdik employed a realist approach, while Hale Asaf and Muhittin Sebati leaned towards Romanticism, and Refik Epikman was inclined towards Cubism. Additionally, Ali Avni Çelebi and Zeki Kocamemi reflected the influence of German Expressionism in their works.

Subsequently, the D Group (1933-1947) artists aimed to paint with constructivist and structuralist approaches, moving away from Impressionism. They avoided realism and imitation of nature in their works. As a result, the artists of the Republic period produced unique works in figurative designs, constructivist approaches, and geometric construction techniques (Baytar, 2014, p. 178-179).

In painting, binders such as linseed oil and walnut oil are necessary to hold the paints together and apply them to the surface. It is known that during the Ottoman period and even in the Republican period, linseed oil, also known as linseed oil, was frequently used as a plant-based binder (Şerifaki & İpekoğlu, 2021, p. 499). According to FTIR-ATR results, the binder used was determined to be linseed oil.

According to the SEM-EDX analysis results conducted on the primer layer, it was determined to be zinc white, titanium white, lithopone, and lead white. We know from sources that artists apply a primer layer using colors like zinc white, titanium white, or lead white to

saturate their canvases, achieve whiteness, and increase opacity, or that pre-made high-quality canvases are already saturated and primed.

In the investigation of pigment contents, HPLC-DAD analyses were performed for organic contents, but no organic dyes were detected. Subsequently, SEM-EDX analyses were conducted to identify inorganic pigment contents. According to the analysis results, the colors used by the artist while depicting the landscape include ultramarine, cadmium red, manganese oxide, Guignet green, and lead red (Minium), whereas the colors used for the nude figure include Prussian blue, Brunswick green, zirconium oxide, and black iron oxide.

It was also determined that there are common colors used on both surfaces. These colors are zinc white, lead white, green earth/Verona green, ivory/bone black, lithopone, molybdate red, and permanent/barium white. Of the 16 colors used by the artist while depicting both the landscape and the nude figure, 7 are the same (Image 18). Based on the analysis results, the artist's palette colors were identified, and the similarity of the paints used on both surfaces suggests that both paintings were created by the same artist.

Image 18: Distribution of pigments used in the painting (Drawing: Betül Küçük)

In order to date the artwork, the discovery dates and commercial production times of the colors used by the artist were researched through literature, and the scale was narrowed down (Image 19).

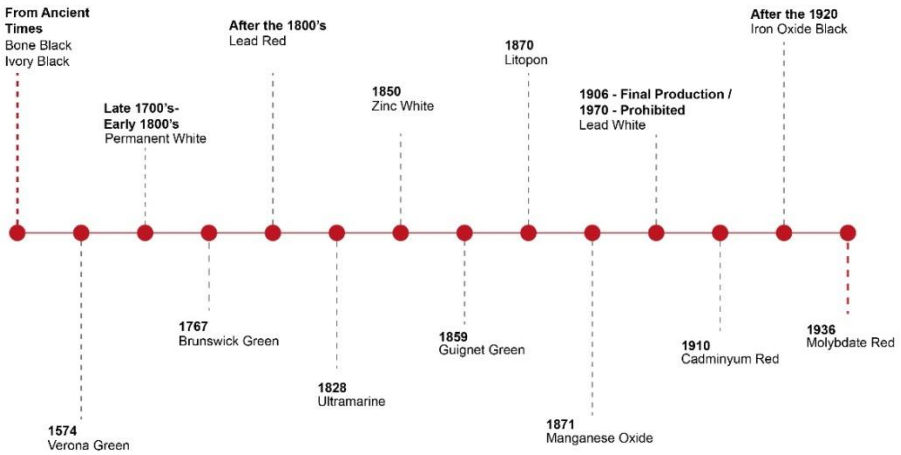


Image 19: Chronological order of the historical research on the pigments identified according to the SEM-EDX analysis results (Drawing: Betül Küçük).

Based on the examination of pigment production and usage dates, it was considered that the painting could not have been created before the commercial production of molybdate red started in 1936, suggesting that the painting was made in 1936 or later. Additionally, the fact that the artist did not draw the Bosphorus Bridge in the landscape-themed surface indicates that it had not been constructed yet. It is known that the construction of the Bosphorus Bridge began in 1970 and its official opening was on October 30, 1973.

When sources and photographs of the period are examined, it can be seen that the bridge's pylons were present from 1971 onwards. Therefore, it can be assumed that the painting was made before 1970. However, it would not be accurate to make a definitive statement on this matter. The artist might have made the painting based on an old photograph or postcard, or could have interpreted the scene differently. Thus, it is very difficult to make a precise determination regarding the dating of the painting.

Dendrochronological analyses conducted on the stretcher revealed the date 1913; however, it is difficult to date the processed wood accurately due to the unknown number of rings that were cut and discarded. Nevertheless, it is possible to say that the stretcher belongs to the period in which the painting was made.

It was determined that zinc white, titanium white, lithopone, and lead white were used in the primer layer, but more comprehensive analyses are needed to determine whether the canvas was primed by the artist or if a pre-primed canvas was purchased.

The types of binders used in the primer layer, fiber sample, and pigments were investigated using FTIR-ATR, and linseed oil was identified as the binder in all the examined samples.

The painting studied within the scope of this research is unsigned, and the artist is unknown, resulting in a lack of comparative examples. Although the research on pigment analyses identified that molybdate red started to be used by artists after 1936, allowing the painting to be dated within this timeframe, it was not possible to attribute it to a specific artist.

Finally, various artists who produced works close to the constructivist style within art history were researched. Works by different artists that showed similarities with the painting examined were found. For instance, Cemal Tollu's work "Boat on the Bosphorus" shows similar constructivist style drawings. The elements constituting the composition are deformed and depicted differently than they appear. Tollu used rapid brush strokes in his paintings. Especially in his painting "On the Bosphorus," the barely visible figure in the boat bears a resemblance to the barely visible bird form drawn on the roof in the examined painting (Table 11 a-b).

The exact dating of the painting remains challenging, but the stylistic and compositional similarities to works by Cemal Tollu offer some insight into its possible origins (Table 11).

Refik Fazıl Epikman's works such as “Nusretiye Mosque”, Saim Özeren's “Mosque” and “Front of Selimiye”, and Halil Dikmen's “Landscape”, where they drew the minarets of the mosque but did not provide details, and in Refik Fazıl Epikman's work “Landscape”, the barely visible drawing of the opposite pier with rapid and broad brush strokes, deforming the composition elements, shows that it carries similar styles to the examined painting (Table 11).

The woman figure drawn on the surface with the nude theme bears stylistic similarities to Zeki Kocamemi's painting “Nude” and Halil Dikmen's painting “Sitting Woman”. The common feature in all paintings is the deformed lines and the avoidance of details (Table 12).

Despite all this, more definitive and clear results require the examination and comparison of the works of the mentioned artists using scientific and visual analysis methods. Although a definitive date could not be reached in the study, the timeframe has been narrowed. It is hoped that future studies will address the issue and examine it using analytical methods.

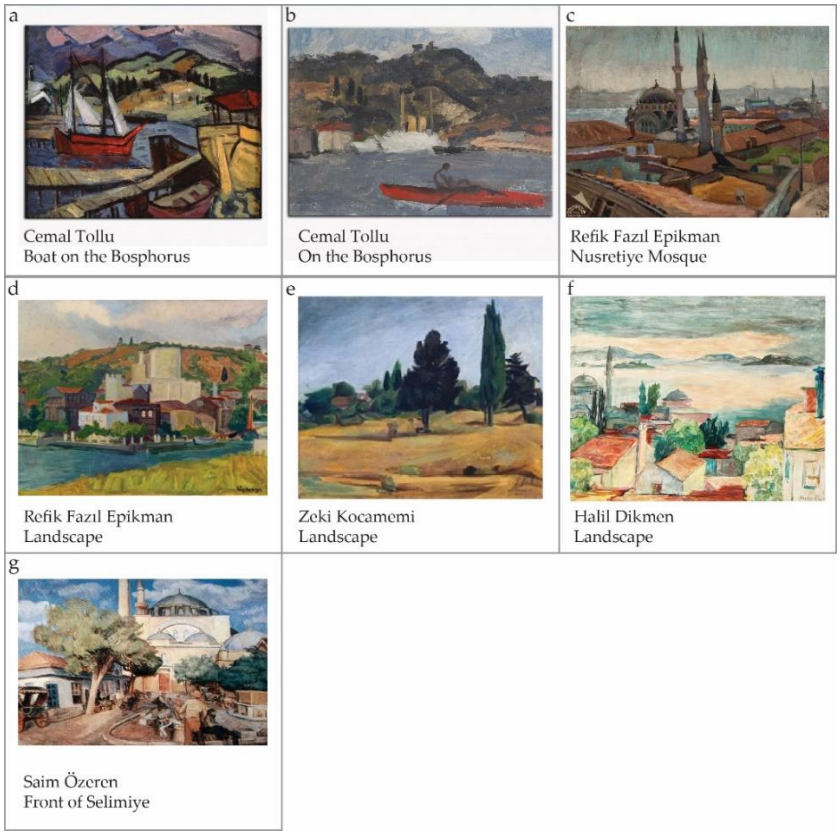


Table 11: Artists who have created similar works with the subject of landscape. a),b)(https://www.istanbulsanatevi.com/turk-ressamlar/cemal-tollu-hayati-ve-eserleri-1899-1968/, 2023), c) (Giray, 2004, s. 134), d) (Yasa Yaman, 2012: 263), e) (Yasa Yaman, 2012: 251), f) (https://artam.com/muzayede/331-online muzayede/halil-dikmen-1906-1964-peyzaj, 2023), g) (Çoban & Işık, 2019: 1875).

Table 12: Artists who create similar works with nude female figures, a) ("Türk Resminde Çıplak", Galeri Baraz, İstanbul, 1981", Salt Araştırma, https://archives.saltresearch.org/handle/123456789/212161), b) (Yasa Yaman, 2012: 242), c) (https://artam.com/muzayede/335-online-muzayede/halil-dikmen-1906-1964-oturan-kadin, 2023).

Ethical Statement/*Etik Beyan*

The study titled "*Copying And Forgery in Oil Paintings: Researching And Application Example Of Identification Of Authenticity By Scientific Analysis*" has been conducted in compliance with scientific, ethical, and citation principles. No alterations have been made to the collected data, and this work has not been submitted for evaluation to any other academic publication platform. This study does not require an ethics committee approval. The article has been prepared in accordance with the ethical guidelines of Anasay Journal, which are based on the principles established by the Committee on Publication Ethics (COPE) for authors, reviewers, and editors.

Hakem Değerlendirmesi: Dış bağımsız

Çıkar Çatışması: Yazar, çıkar çatışması olmadığını beyan etmiştir.

Finansal Destek Bu çalışma, İstanbul Üniversitesi Bilimsel Araştırma Projeleri Koordinasyon Birimi tarafından desteklenmiştir, Proje Numarası: 37788.

Peer-review: Externally peer-reviewed.

Conflict of Interest: The author declares that they have no competing interest.

Financial Support: This study was funded by the Scientific Research Projects Coordination Unit of Istanbul University, Project Number: 37788.

Acknowledgements

This study was funded by the Scientific Research Projects Coordination Unit of Istanbul University, Project Number: 37788. The authors are deeply grateful to the Scientific Research Projects Coordination.

Within the scope of the study, we would like to extend our gratitude to Prof. Dr. Ahmet Kamil Gören and Assistant Prof. Dr. Ahmet Özel for their contributions to art history examinations, to Prof. Dr. Ünal Akkemik, Head of the Department of Forest Engineering, Faculty of Forestry, Istanbul University, for performing and interpreting dendrochronology analyses, and to Prof. Dr. Recep Karadağ for sharing his expertise in conducting and interpreting scientific analyses such as HPLC, FTIR-ATR, SEM-EDX, and fiber analysis.

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