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SPECTRAL STUDY OF THE MURAL PAINTING DEGRADATION IN WOODEN CHURCHES

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Abstract: The aim of the paper is a spectral study of a mural fresco from Serbesti wooden church, Dambovita county, partially painted, a historical monument from 1828 (or 1804 after some other documents). Spectral techniques as X-ray Fluorescence wavelengths dispersive (WDXRF), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) or Raman spectroscopy, have been used in order to highlight the presence of the degradation processes. Also, the chromatic parameters have been used as additional data in order to observe the discoloring aspect of these mural fresco.

Keywords: *Serbesti wooden church, pigments, analytical investigations*

1. INTRODUCTION

Wood is an essential material to human society with various characteristics for every application [1]. Wood has an important role in the cultural heritage either as structural beams, painted or gilded panels, furniture items, statues and icons of both artistic and religious value, etc. Most often, old wooden objects present evidence of active infestation, besides historical biological degradation by insects or fungi, who affect their structural integrity, physical and mechanical properties [2-4].

As for the pictorial technique, the wooden churches in the Carpathians area of Curvature fit into the art of the XIX century, which was not determined by official art [5], but by the traditional one. The decorative and picturesque character of the XVIII style started from the emancipation tendencies in the forms of traditional painting implemented by painters' craftsmen from Wallachia [6].

Now begins a laborious and active era in which the painters of churches and icons have a continuous dialogue with the past, rediscovering the beauty of the old Byzantine paintings, which they reintegrate into a new formula to the artistic ensembles of the time.

In 1982 it is defined the technique specific to the execution of mural paintings in Maramures, as a thin primer evenly stretched on the architectural wooden support, and at the intersections between the beams are glued narrow textile strips of 7-8 cm. The painting executed on top is a weak tempera [7]. The mural painting on wood in poor tempera is part of the technique of Romanian tradition, made from "the oldest times until the nineteenth century" [8].

The transition from one era to the other influenced not only the stylistics of painting, as we have seen, but also the technique of execution, which was replaced from that in poor tempera with oil painting. It is obvious that the wooden churches have in the past received a painting with a diluted binder in a watery base, later transformed into an oil-based binder. We will notice that the transition to the oil colors also influenced the support on which they were applied. In many works of art, oil painting on the board could be find inside the wooden churches, above the vertical planks. This is a newly encountered technique that falls into the area of late interventions of the early twentieth century [9].

The aim of this paper is to study the mural fresco from Serbesti wooden church, Dambovita county, partially painted, a historical monument from 1828 (or 1804 after some other documents). Spectral techniques as X-ray Fluorescence wavelengths dispersive (WDXRF), X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) or Raman spectroscopy, have been used in order to highlight the presence of the degradation processes. Also, the chromatic parameters

have been used as additional data in order to observe the discoloring aspect of these mural fresco.

2. MATERIALS AND METHODS

The investigated samples have been collected from the wooden church of Şerbeşti, 1828 from Frasin Deal, Dâmboviţa county, Figure 1. The samples were detached samples, without any patrimonial value.

The painted fresco from the iconostasis of the church, about 3 cm long, both materials found on the wooden floor, detached, also, without heritage value, Figure 2. P1 is the back side of this fresco and P2 is the coloured part of this fresco.



Figure 1. The wooden church of Şerbeşti, 1828 from Frasin Deal, Dâmboviţa county



Figure 2. The painted fresco from the iconostasis of the church

3.CHARACTERIZATION METHODS

Rigaku Ultima IV diffractometer (Rigaku, Tokyo, Japan) has been used for X-ray diffraction (XRD) analysis with the following parameters: Cu Kα radiation (λ = 1.54 Å), scanning range 2θ= 10º - 80º, and a scan rate of 4º/min.

X-ray Fluorescence Spectrometer wavelength dispersive (WDXRF) (Rigaku, Tokyo, Japan, with a Pd anode with a power of 200W (tens. 50kV, int. 4mA), detection limit: 1ppm – 10ppb and accuracy <0.1-0.5%.

Optical microscopy (OM) images were obtained with a Novex trinocular microscope (EUROMEX Microscopen B.V. HOLLAND) (magnifications: 40X, 100x, 400x, 1000x).

Fourier transform infrared spectroscopy (FTIR) has been performed with a Vertex 80 spectrometer (Bruker Optik GMBH, Germany), with DRIFT accessory in the range of 4000–400 cm^{-1}.

Raman spectra have been measured with a portable analyzer (Rigaku, USA) equipped with two laser wavelengths: 785 and 1064 nm, resolution of 4 cm^{-1}.

Chroma Meters CR-410 colorimeter (Konica Minolta, Tokyo, Japan) has been used for chromatic parameters. The parameters determination in CIE L*a* b* system was made according to EN 15886 and ASTM 2244. ΔL* is the difference in lightness (ΔL*), Δa* is the chromatic deviation of the a coordinates (red and green color) (Δa*), and Δb* is chromatic deviation of the b coordinates (yellow and blue color) (Δb*), changes calculated reported to the control samples.

4.RESULTS AND DISCUSSIONS

In south part of Romania (Wallachia) the Byzantine influences were the most significant trend in churches buildings. The monuments in the south of Romania are not very tall. The spaces tend to reproduce the apses of the masonry churches, by widening the central part.
The wooden church is a spiritual element of great significance for the community, especially since it has around it a cemetery where the loved ones of that community rest. Together with the other wooden churches located in the surroundings: (Frasin Vale, Frasin Deal- Copăceni and Mislea), the wooden church from the village Frasin Deal- Şerbeşti, represents a cultural landscape present in different forms in the rural area of the Cobia Valley.
This church is the third oldest in this area, laying its foundation in 1828 during the priest Micu, is also the most beautifully monument, being the largest one from this region. It is built like the other two churches, especially since, in 1850, it is plastered both inside and outside and painted on fresco by the painter Dițu Tănase from Târgovişte. Today, this painting is largely destroyed, due to the consolidation works of 1980 and the intervention made on it during the communist period. The wooden place of worship, built in 1828 (or 1804 after other documents) with interior decorative elements, is a witness of the tradition of construction, developed in Romanian villages. This represents an important technical and artistic achievement of vernacular religious architecture.

Besides the constructive technique and execution of interior painting, the wooden churches have withstood the unfavorable conditions of the time for hundreds of years [10].
The analysis of the degradation factors starts from the execution technique, most of the times the technical vices are those that devastatingly affect the ensemble. The preservation of wooden buildings depends very much on placing the beams on a stone pedestal and caring for the roof, but also on obstructing the interstices between the beams. If all these components are made according to the old traditions and respecting the minimum conservation principles, then the ensemble

will present an adequate state of preservation. Important in the preservation of wooden constructions is also preventive monitoring, daily care of the edifice, under observation.

The architectural monument that presents various techniques of folk craftsmen can have multiple degradations as an effect of various causes. There is an interdependence between these causes, one creating favorable conditions for the entry into action of another. In some cases, the effect may occur late after the action of the cause and may sometimes be prolonged for a long time after the elimination of the cause. For this reason, it is necessary to carry out a technological analysis and at the same time to know the history of chaining the causes and effects in time that have generated the current degradations. The analysis of the changes suffered during the opera time is necessary in order to be able to decide the treatment and then act efficiently on the causes, by reducing them, it is also ensured the long-term protection of the monument or object.

The most fragile to the action of degradation factors are objects made up entirely or partially of organic matter. Of the organic materials wood and paper were most often used in painting.

The parietal of the wooden churches keeps the painting made in watercolors, sensitive to the action of several degradation factors, in most cases they act simultaneously.

The degradation factors that affect the mural painting in the wooden churches can be divided into the following categories:

- Physical factors or physical causes: humidity, temperature, light, fire, vibrations, dust, various deposits in the atmosphere [11].
- Chemical factors: chemical instability of materials.
- Biodegradation caused by: insects, bacteria, fungi, algae, lichens, animals (bats, rodents, birds), plants.
- Human activity causes degradations on the work of art through: technical defects (use of materials in an inappropriate way), improper storage conditions, faulty treatments, improper handling, the function of the object, negligence, etc.
- External factors of circumstance: fires, floods, earthquakes.

Each of these factors causes degradations on the work of art, but not all of them can influence the appearance of gaps in the case of paintings on a wooden support.

Microclimatic variations create local tensions that lead to detachments, untangling, flaking and finally gaps in the pictorial layer. The sudden loss of moisture content induces cracks and deformations of the wood material. The same effects result from the heating of the surfaces by bright lighting with the help of incandescent spotlights on the respective surfaces [12].

Generally, works of art are affected by three large classes of factors: natural (physical and chemical), biodegradation factors and anthropogenic factor. The physical factors are in a close connection and are also influenced by the original matter in the work of art, for example: the hygroscopic character of the wood. Changes caused by microclimatic instability are the main cause of physical factors.

The support of paintings on wood is an organic material and degrades due to:

- internal factors: the wood species, the structure of the wood composition; changes in the volume of the wooden panel (due to the hygroscopic character of the wood that balances the amount of water in the substrate according to the ambient environment; this change also influences the flatness of the panel according to the wood essence, the way of trimming, the preparation of the wood panel by joining the countertops, the strengthening elements, etc.)
- external factors: microclimate conditions and the human factor. External factors can be of a physical, chemical and biological nature.

The factor that most obviously influences the conservation state of the paintings on wood and conditions the other factors is the "humidity", and the most accentuated degradation occurs when the cycle of increase and decrease of humidity is repeated. Each increase or decrease in the relative humidity implicitly influences the changes in the amount of water in the wood substrate, which generates a series of swellings and contractions, putting the most serious problems in the preservation of the painting.

The humidity type that are registered at the buildings, are:

- infiltration moisture – introduced through the roof due to defects in the coating system;
- the humidity of capillary, introduced from the moist soil, which climbs through the capillaries of the walls and meets at the base of the wall, it can occur at the wooden churches only in the case of the stone plinths that will influence the sole at the base of the walls.
- condensation humidity occurs when the warm air in the atmosphere meets the cold surfaces of the walls.

Depending on the different conditions of the ambient environment in which the works of art will be located, three categories can be classified, being directly influenced by the relative humidity.

The conditions for the preservation of the classified movable cultural goods have values between 50-65% for the U.R. and the temperature should not exceed 22 ^{o}C.

If the relative humidity drops below 50%, and the temperature has high values, then dryness conditions appear and negatively influence the preservation of works of art, causing: wood contractions that produce cracks, cracks, detachments, of the color film, the materials becoming brittle.

The greatest degradations occur when there are fluctuations in temperature and humidity, so it is more favorable to have a higher or lower ambience than recommended, but it remains constant, without any modification. The dryness induced by the "central heating" negatively influences the preservation of works of art. The sudden loss of water changes the volume, which leads to the appearance of cracks, detachments and finally gaps.

The processes of degradation of works of art are influenced by temperature especially when its values are excessive. As with humidity, sudden transitions from one extreme to another, cause the greatest degradation, in this case the transition from frost to thaw. The high temperature also causes low humidity. In dryness situations, the wood structure suffers great contractions and cracks and cracks are produced that influence the pictorial layer and its gaps are produced.

The natural movements of the wood are accelerated by the microclimate conditions and lead to the cracking of the pictorial layer and to the detachment from the support. The composition of the pictorial layer that has the role of slowing down the vibrations and the danger of degradation of the color film is the primer.

Fire is also a risk factor for wooden churches. They come into direct contact with painting and produce the phenomenon of carbonization. Certain pigments are influenced by the heat caused by open fire, so the carbonate turns into calcium oxide, which then absorbs a new amount of vapor, alters the tones of the pigments. Iron oxide can pass from yellow to red-brown through chemical change in composition. In addition to charred pigments, the same phenomenon is also produced at the level of the wooden support, which will in this case be irreversibly degraded.

In the case of paintings in fatty tempera or oil that have been covered by verni, the forms of degradation produced by the interior fires are presented as elevations, oaks that lead to

then towards carbonization. Depending on the depth to which the fire reaches, the carbonization irreversibly degrades, permanently losing itself from the outside to the inside of the matter, thus from verns, pigments, primer, canvas support, wood, etc.

Light is a physical factor that directly influences the hue of pigments through UV radiation. The most harmful is natural light that propagates the most radiation, then artificial sources are cataloged by the degree of radiation and the power with which it iluminate on the work of art.

Regarding the degradation caused by human activity, they can be influenced by many causes induced by human activity:

- technical defects: use of an incorrect working technique, wooden beams prone to its deformation, improper constructions, use of already degraded materials, etc. [13];
- improper storage conditions: maintaining the monument in conditions of excessive humidity, excessive temperature, strong light, negligence leads to massive degradation of the monument to the ruin.
- handling of interior objects: transport, storage under adverse conditions. Depending on the activity of the human factor, the external factors of degradation are also conditioned.
- improper interventions: improper repairs, various installations, posters, icons, etc.

As a historical specification, the Dâmbovița area includes, besides other tourist attractions, wooden churches both from the XVII, XVIII and XIX-th centuries. The transition period from folk art to the realistic style of the nineteenth century technologically marks the mural painting of wooden churches. The analysis of the construction technique reveals some changes in the architecture, either by increasing the space, or by replacing the roof or by adding new elements, interventions while sometimes having a negative effect on the whole ensemble. These changes have influenced both technically and stylistically including the mural decoration.

Environmental factors had a rather large influence on the conservation status of the roofs of wooden churches, which were degraded over time and changed by number of times.

Most of the degradations in the case of wooden churches are brought by the anthropic factor that does not preserve the historical monument in its own conditions [14].

The degradations produced due to the human factor are diverse, of which the most serious form of degradation is the production of gaps either in the wooden structure or in the pictorial matter. The lacuna represents the last phase of degradation, being caused by other forms of degradation presented above. Until we reach the last phase, that of the gaps, the forms of degradation that appear are multiple and due to the fact that they are provoked at the level of the support that implicitly influence the primer and color layer, or it happens only at the level of the color layer.

The forms of degradation at the level of the pictorial layer: cracks due to aging, cracks of the pictorial layer, detachments, networks of cracks, superficial cracks, longitudinal cracks, elevations in two waters, marginal elevations, elevations with a tendency to collapse, mechanical degradations – blows, scratches, erosions due to the manipulation of the object, which ultimately lead to the appearance of gaps.

The excessive increase in the amount of moisture in the substrate creates favorable environments for the development of microorganisms, thus attacks of fungi occur on the primers, the wood structure, the glues disaggregate, they cause the detachment of the colors, all the more so as they already have cracks or are not protected with varnish, there are losses of the color layers (washings of the color film due to excessive humidity).

Degradations caused by the human factor due to the materials used by the artists also called vices of original technique such as: non-observance of the "fat on the weak" rule can cause degradations at the level of the pictorial layer, exfoliations, cleavages, crackles.

The use of certain pigments, such as Prussian blue, vermillion, transparent lakes mixed with whites, with sulfur-based pigments, considered of poor quality, is another cause that will lead to multiple degradations of mural paintings.

The technical defects can continue with the use of erroneous proportions, the omission of some primer components with high proportions of glue, causes that lead to the appearance of premature cracks given by the high concentration of binder compared to the aggregate.

Degradations due to faulty, unscientific treatments, negligent manipulations such as: faulty treatments – unscientific interventions, restorations of circumstance, changes in shape and size that can produce the lacunae of the pictorial layer.

- the cleaning operation with aggressive, basic or acidic substances that can produce erosions of the aisle layer, or inappropriate substances: candy oil. All these factors contributed to the irreversible degradation of the investigated fresco, and the spectral analyses came to support this statement.

In the FTIR spectra (Figure 3), some series of specific bands were identified as markers of identification [15-18]:

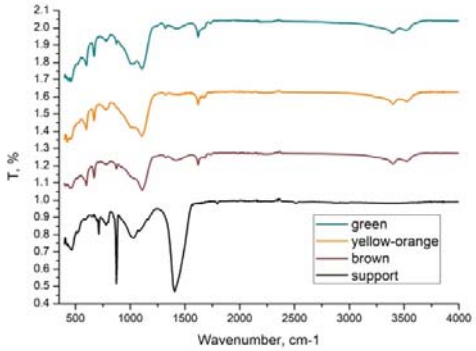

Figure 3. FTIR spectra of the support and the pigments used for murale frescoes

The FTIR analysis of the collected samples indicated different inorganic phases and organic products, as follows:

- stretching vibrations of calcium carbonate ($CaCO_3$), peaked at 1409, 705 and 611 cm^{-1}.
- vibrational bands of gypsum ($CaSO_4 \cdot 2H_2O$), centered at 1109, 669 and 596 cm^{-1}, and its related forms (bassanite and anhydrite).
- The characteristic bands of thenardite, centered at 1034 cm^{-1}, were also found, as a first proof for degradation process of the rock.
- stretching vibrations of an organic resin, centred at 944 cm^{-1} (C-O), l365 cm^{-1} (C-H), 1735 cm^{-1} (C = O).
- clay minerals with the peaks from 1032 cm^{-1} (Si–O–Si bond) [19].
- 3500 cm^{-1} (hydroxyl compounds), 1776, 1734 and 1714 cm^{-1} due to the carbonyl species, obtained by triglyceride oxidation.

FTIR spectra could be correlated with Raman spectra (Figure 4), where the common features were a band around 1006 cm^{-1}, corresponding to the strongest vibration of calcium sulphate, and bands around 900 cm^{-1}, 1250 cm^{-1}, 1300 cm^{-1}, 1440 cm^{-1}, which correspond to the Raman spectrum of linseed oil binder [19].

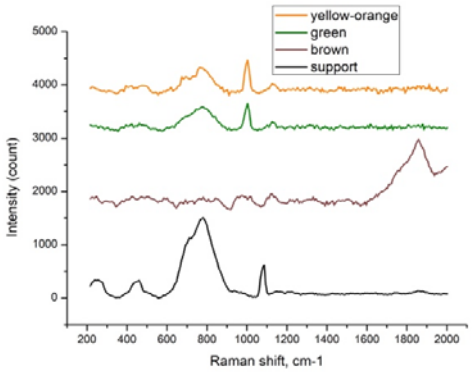

Figure 4. Raman spectra of the substrate and the pigments from mural frescoes

The main bands of Raman components are 294, 408 and 606 cm^{-1} assigned to hematite, 299, 389 and 548 cm^{-1} assigned to goethite and 1190, 1289 and 1545 cm^{-1} assigned to green earths present in green colour. These results can also be argued with X-ray fluorescence data, according to Table 1.

Table 1. Elements and their concentrations on the investigated samples (P1=substrate; P2=green pigments)

Element	Concentration ± SD, %	
	P1	P2
Mg	0.734±0.160	0.8834±0.127
Al	2.2926±0.043	2.2492±0.050
Si	8.14±0.058	6.6368±0.049
P	0.0661±0.016	0.1079±0.015
S	0.8579±0.014	0.8093±0.012
Cl	0.096±0.013	0.0763±0.012
K	0.7078±0.045	0.5608±0.039
Ca	49.9173±0.052	52.4941±0.051
Ti	0.2214±0.092	0.3741±0.085
Fe	2.4359±0.039	1.9126±0.035
Sr	0.0839±0.019	0.0754±0.018
Mn		0.132±0.043

The concentrations of the elements are comparable in value, which can denote the migration of pigments (P2) from the painted part to the substrate (P1), or the restoration mistake practiced in the 1980s on this fresco. From XRD results, the main mineral products could be identified, the major components being calcite, quartz, aluminosilicate

Table 2. XRD data of the investigated samples

Phase name (P1)	Formula	Content(%)
Calcite, syn	$Ca(CO_3)$	43.8(6)
Quartz, syn	SiO_2	22.4(4)
Potassium Phosphorus Hydride	K(PH2)	4.0(3)
Magnesium Oxide	MgO	3.7(2)
Zoisite, Sr-bearing, syn	$Sr_{0.76}Ca_{1.24}Al_3(SiO_4)(Si_2O_7)O(OH)$	8.9(4)
Clintonite-1M	$CaMg_{2.2}Fe_{0.2}Al_{3.4}Si_{1.2}O_{9.9}(OH)_{2.1}$	17.2(8)

Phase name(P2)	Formula	Content (%)
Calcite, syn	$Ca(CO_3)$	55.2(10)
a-Si O2, quartz, syn	SiO_2	21.7(6)
Graphite-3R	C	17.0(13)
Manganite	MnO(OH)	2.3(3)
Ramsdellite	MnO_2	1.4(2)
dipotassium lithium catena-di-μ-phosphidoaluminate	K_2LiAlP_2	1.8(3)
Ilmenite, syn	$TiFeO_3$	0.5(5)

Colorimetric measurements (CIELab) included L*, a* and b*, which represent: brightness (0 for black − 100 for white), a*, which is the red–green component (positive for red and negative for green) and b* is the yellow–blue component (positive for yellow and negative for blue), respectively.
The measurements revealed only positive values for Δa* (red component); Δb* parameter shows positive (yellow samples) and negative (brown and green samples) values indicating yellow and blue colour, respectivelly. Because the parameter ΔL* has only negative values, they are indicating darken aspects of the samples, Table 3.

Table 3. The chromatic parameters of the investigated samples

Sample	ΔL*	Δa*	Δb*
Yellow	-42.71	7.25	13.02
Green	-33.75	1.85	-1.14
Brown-black	-76.08	2.6	-14.68

5.CONCLUSIONS

FTIR based on both the specific absorption bands for structure and the peaks from the 600-400 cm^{-1} range. The FTIR bands are well correlated with Raman results.

Based on XRD diffractograms, the major components are calcite, quartz and different clays. Manganite are responsible for green color, and iron oxides for red colors. These components have elements identified by WDXRF.

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REFERENCES

[1] Williams RS, Weathering of wood. Handbook of wood chemistry and wood composites, 2005; 7: 139-185.

[2] Ion RM, Nyokong T, Nwahara N, Suica-Bunghez IR, Iancu L, Teodorescu S, et al. Wood preservation with gold hydroxyapatite system, Heritage Science. 2018; 6(1): 1-12.

[3] Richardson B, Wood Preservation. 2002: Routledge.

[4] Alfieri P, Lofeudo R, and Canosa G, Impregnant formulation to the preservation, protection and consolidation of wood heritage assets, International Journal of Conservation Science, 2018; 9(4): 629-640.

[5] Alpatov, M., Istoria Artei, vol II, Arta renașterii și a epocii moderne, Ed. Meridiane, București, 1965, p.330.

[6] Porumb M., Pictura românească din Transilvania, Ed. Dacia, Cluj-Napoca, 1981, p.93.

[7] Bratu, A., Pictura Murală Maramureșeană, Meșteri zugravi și interferențe stilistice, Editura Meridiane, București, 1982, pp.19-20.

[8] Postolache, L.D, Tehnica de execuție a picturii murale din bisericile de lemn și forme de degradare specifice acesteia, Restitutio, Buletin de conservare-restaurare, Muzeul Național al Satului ”Dimitrie Gusti”, București, 2013 p.126.

[9] David ME, Ion RM, Andrei ER, Grigorescu RM, Iancu L, and Filipescu MI, Superhydrophobic Coatings Based On Cellulose Acetate For Pinewood Preservation. Journal of Science and Arts, 2020; 1: 171-182.

[10] Ion, R.M., Poinescu, A.A., Teodorescu, S., Stirbescu, R.M., et al., Degradation of wood decorations from 18th century old houses, The Scientific Bulletin of VALAHIA University – MATERIALS and MECHANICS, 10 (13) 2015, 25-30.

[11] Ashley-Smith, J., Current Thinking on Environmental Standards in Conservation Matters in Wales/Challenging Buildings: Search of Solutions, Conference Postprints. Henderson, J. (ed), Cardiff, 2006, 10-14).

[12] Moldoveanu, A., Conservarea preventivă a bunurilor culturale, Ministerul Culturii, București, 2003.

[13] Mora, P., Mora, L., Philippot, P., Conservarea picturilor murale, Traducere de Dan Pineta, Ed. Meridiane, București, 1986, p. 210.

[14] Necula, E.T., Degradări ale picturilor murale din bisericile de lemn, Caietele restaurării 2013, Ed. ACS, București, 2013, p.65.

[15] Ion, R.M., Ion, M.L., Raditoiu, V., Darida, I., Postolache, D.L., Non-destructive and microanalytical techniques for composition and structure identification of the wall materials from palace of Potlogi, The Scientific Bulletin of Valahia University – Materials and Mechanics, 10 (13) 2015

[16] Feller, R.L. Barium sulfate-natural and synthetic. In Artists' Pigments; A Handbook of Their History and Characteristics; National Gallery of Art: Washington, DC, USA, 1986; Volume 1, pp. 47–64.

[17] Berkesi, O., Katona, T., Dreveni, I., Andor, J.A., Mink, J. Temperature-dependent Fourier transform infrared and differential scanning calorimetry studies of zinc carboxylates. Vib. Spectrosc., 1995, 8, 167–174

[18] Robinet, L. & Corbeil, M. C. The Characterization of Metal Soaps. Studies in Conservation 2003, 48, 23–40.

[19] Osmond, G., Boon, J.J., Puskar, L., Drennan, Distributions in Modern Artists' Oil Paints: Surface and Cross-sectional Investigation of Reference Paint Films Using Conventional and Synchrotron Infrared Microspectroscopy. Appl. Spectrosc. 2012, 66, 1136−1144.