Dolma-tekke in Kruja (Albania): A preliminary research approach to interior artistic decoration, techniques, and materials used

Dolma-tekke en Kruja (Albania): un enfoque de investigación preliminar sobre la decoración artística del interior, las técnicas y los materiales utilizados

Edlira Çaushi [1] and Erinda Ndreçka [2]

University of Tirana [1] and [2]
Department of Archaeology and Culture Heritage
1001 Elbasan Str., Tirana (Albania)
caushiedlira3@gmail.com [1] e.ndrecka@outlook.com [2]
ORCID: https://orcid.org/0009-0000-2921-4473 [1] /
https://orcid.org/0009-0002-9590-416X [2]
Fecha de envío: 21/4/2026. Aceptado: 4/9/2026
Referencia: *Santander. Estudios de Patrimonio*, 9 (2026), pp. 201-230.
DOI: https://doi.org/10.22429/Euc2026.sep.09.05
ISSN-L e ISSN 2605-4450 (ed. impresa) / ISSN 2605-5317 (digital)

Resumen: El trabajo estudia las pinturas murales de Dolma-tekke en Kruja, un monumento significativo del patrimonio arquitectónico y artístico otomano de Albania de los siglos XVIII-XIX, de gran valor para la preservación de la identidad cultural de los Balcanes en el contexto de desafíos actuales como la urbanización, el cambio climático y la pérdida de bienes históricos debido a desastres naturales. El objetivo del trabajo fue determinar las características de la decoración interior, las técnicas de ejecución y los materiales utilizados en la pintura decorativa, así como establecer su estado de conservación. Para lograr este objetivo, se aplicó un conjunto de métodos: análisis histórico-artístico, trabajo de campo, fotofijación, escaneo tridimensional y mediciones microclimáticas.

Palabras clave: restauración; pintura mural; pigmentos; técnica pictórica; análisis arqueometrico; conservación, Albania.

Abstract: The work was devoted to the study of the wall paintings of Dolma-tekke in Kruja, a significant monument of the Ottoman architectural and artistic heritage of Albania of the XVIII-XIX centuries, which had great value for the preservation of the cultural identity of the Balkans in the context of current challenges such as urbanisation, climate change and the loss of historical objects due to natural disasters. The aim of the work was to determine the features of interior decoration, techniques of execution and materials used in decorative painting, as well as to establish the state of preservation. To achieve the aim, a complex of methods was applied: art-historical analysis, field surveys, photofixation, three-dimensional scanning, microclimate measurements.

Keywords: restoration; mural painting; pigments; technique of execution; archaeometric analysis; conservation, Albania.

*****

1. Introduction

Dolma-tekke in the city of Kruja was one of the outstanding examples of the Ottoman architectural and artistic heritage of Albania of the XVIII-XIX centuries, which combined cult, historical-cultural and artistic values. The interior painting of the building preserved unique decorative programmes with distinct Ottoman and Baroque features, which reflected the synthesis of local traditions and cultural influences. The significance of the object grew in the context of active discussions on the protection of sacred monuments of the Balkan region, especially those damaged by natural and anthropogenic factors. The state of preservation of Dolma-tekke was complicated by cracks, plaster delamination, salt crystallisation and damage after the 2019 earthquake, which made comprehensive scientific research relevant for the determination of materials, techniques of execution and the development of effective approaches to restoration.

Studies of Ottoman monumental painting in Albania were conducted mainly in the art-historical context and concerned the architectural typology of tekkes, iconography and stylistics of decoration. In the works of Turkish, Italian and Albanian researchers, attention was paid to the general characteristics of interior décor and its comparison with other cult monuments of the Balkans. At the same time, in international publications of the latest decades, archaeometric approaches to the analysis of materials and techniques of painting occupied a significant place, which made it possible not only to clarify the technology of creation but also to identify the factors of destruction.

The study of Papa and Basha[1] revealed characteristic floral, geometric and landscape motifs in the wall paintings of Ottoman religious buildings of Albania, in particular Dolma-tekke, executed in the *a secco* technique with the use of black, red, grey and yellow pigments. This emphasised a unique balance between ornamentality and simplicity, which reflected local artistic traditions. The results indicated significant degradation due to climatic factors, which made the findings relevant for the development of conservation strategies for materials and techniques in Kruja. This topic was deepened by the work of Çiftçi et al.[2], which proposed non-invasive methods of conservation, such as detailed visual documentation and the use of lime mortars

1 PAPA, Dorina and BASHA, Brunilda, "Wall painting motifs in Ottoman religious buildings in Albania", *Pollack Periodica*, 20(2) (2025), pp. 168-173.

2 ÇIFTÇI, Aynur; PAPA, Dorina; UĞURYOL, Drahşan; XHANARI, Lindita; DELIU, Muharem and AKTAS, Zeynep, "An overview to a collaborative project for the conservation of wall paintings in Ottoman period in Albania and Türkiye", *EJ-ARCH: e-Journal of Architecture*, 4(3) (2025), pp. 22-32.

with pigments. The authors emphasised the importance of preserving the authenticity of the paintings of Dolma-tekke by means of microclimate control. These results were key for the practical approach to the restoration of the monument. The study of Manahasa[3] analysed the restoration of Ottoman mosques, revealing the adaptation of decorative elements such as murals with floral motifs and stucco techniques, which combined local and imported materials. This made it possible to understand the historical context of the decorative decoration of Dolma-tekke. The results were relevant for the assessment of the impact of restoration interventions on the state of the paintings. Sukaj et al.[4] studied the acoustic characteristics of Ottoman mosques, revealing the influence of geometry and reflective materials on the preservation of interiors. The authors proposed non-invasive acoustic panels that did not damage wall paintings. This work was important for the assessment of the impact of the environment on the materials of Dolma-tekke and the development of comprehensive conservation measures.

In the study, Basha and Sağdiç[5] analysed urban changes in Ottoman religious buildings, which influenced the preservation of decorative elements, in particular paintings, in cities such as Kruja. The results emphasised the vulnerability of such monuments to external factors such as climate and earthquakes. The study contributed to the understanding of the context of material degradation in Dolma-tekke. İbrahimgil and Naldan[6] established the influence of the Florentine school on the murals of the Balkan Ottoman buildings of the XIX century, in particular the *fresco-secco* technique with Baroque motifs, which reflected Western artistic influences. These results made it possible to better understand the evolution of techniques and materials used in Dolma-tekke. The study was relevant for the development of conservation methods that took into account historical features. Yetiş et al.[7] in the research considered the remains of wall paintings of the Suleiman Pa-

3 MANAHASA, Edmond, "Revisiting the Ottoman period mosques in Albania: A Critical Observation on Late Interventions", in DRAYSON, Elisabeth, *Europe's Islamic Legacy: 1900 to the Present*, Leiden, Brill, 2022, pp. 130-156.

4 SUKAJ, Silvana; BEVILASQUA, Antonella; CIABURRO, Giuseppe; IANNACE, Gino and TREMATERRA, Amelia, "Ottoman mosques in Albania: Building acoustic exploration inside five case studies", *Buildings*, 11 (10) (2021), 430, https://doi.org/10.3390/buildings11100430

5 BASHA, Brunilda and SAĞDIÇ, Zafer, "Urban and architectural alterations in Elbasan from Ottoman period to modernity", *Balkan Studies*, 4 (2) (2024), pp. 53-76.

6 İBRAHIMGIL, Mehmet Zeki and NALDAN, Funda, "The reflection of Florentine (Firenze) school of painting on mural paintings of Ottoman architecture in the Balkans in the 19th century", *Institute of Fine Arts*, 26 (44) (2020), pp. 10-20.

7 YETIŞ, Ezgin; EROĞLU, Murat; ESKICI, Bekir; GÜR, Mahmut; DENIZ, Kiymet, and KADIOĞLU, Yusuf, "Investigations of painting techniques: Edirne Süleyman Pasha Mosque wall paintings", *Studies in Conservation*, 68 (4) (2022), pp. 418-431.

sha Mosque in Edirne. Thanks to scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX), Fourier transform infrared spectroscopy (FTIR), Raman spectroscopy, and portable energy dispersive X-ray fluorescence (PED-XRF) analyses, the use of fresco technique on wet plaster was proved, which differed from the traditional kalem işi. The results testified to the technological diversity of Ottoman wall paintings and the use of mixed techniques. The relevance of the work lay in the recovery of knowledge about forgotten finishing technologies, which formed the scientific basis for the conservation of buildings. In their study, Şerifaki and İpekoğlu[8] investigated the ceiling and wall paintings of an Ottoman mansion in İzmir using optical microscopy, XRD, scanning electron microscopy with energy-dispersive spectroscopy (SEM-EDS), and FTIR. The authors revealed the use of oil technique on a protein basis with a wide range of pigments (lead white, red lead, ultramarine, emerald green). This confirmed the high level of technological processing and the richness of the palette. The relevance of the study was due to the fact that it showed the influence of European artistic practices on Ottoman art and opened perspectives for intercultural comparisons. Kayser et al.[9] conducted an analysis of fragments of paintings in the Church of St Nicholas in Demre, which showed a two-layer plaster structure (arriccio and intonaco) and the use of the *a secco* technique. The use of ochre, calcite, green earth and carbon black as main pigments was established. The study became an important example of the application of archaeometry for the identification of materials of Byzantine and post-Byzantine paintings, relevant also for the Ottoman context. The relevance of the work lay in the demonstration of the possibilities of modern archaeometry for the preservation of the multi-layered cultural heritage of the Balkans.

In scientific studies of 2020-2025, devoted to wall paintings and interior decoration of Ottoman architectural monuments, a number of limitations were traced. The existing works mostly focused on the description of ornamental motifs or partial analysis of techniques and materials, whereas systematic study of the complex combination of artistic style, techniques of execution and factors of degradation remained insufficiently developed. Also overlooked were the long-term influences of microclimate and urban environment on the preservation of wall paintings, which was especially relevant for objects located in conditions open to atmospheric impacts. The absence

8 ŞERIFAKI, Kerem and İPEKOĞLU, Başak, "Execution technique and material characteristics of ceiling and wall paintings of an Ottoman period mansion in İzmir", *Gazi University Journal of Engineering and Architecture Faculty*, 36 (1) (2021), pp. 497-510.

9 KAYSER, Oğuz Emre; ORMANCI, Özden and AKYOL, Ali Akın, "Characterization of wall painting fragments from the West Courtyard Passage at St. Nicholas Church in Demre", *Art-Sanat*, 20 (2023), pp. 293-310.

of an integrated methodology that combined art-historical, archaeometric and conservation approaches made it difficult to form holistic preservation strategies. In this context, the study of the interior decoration of Dolma-tekke in Kruja was aimed at overcoming the mentioned gaps by combining the analysis of artistic solutions, the technical characteristics of materials and the practical aspects of the conservation. The aim of the study was to identify the features of the interior artistic decoration of Dolma-tekke in Kruja by combining art-historical and archaeometric analysis, to determine the materials, techniques of execution and factors of the deterioration. The task of this study was to identify the architectural features, iconography and decorative decoration of Dolma-tekke and to analyse the materials, techniques of execution (*a secco*, *fresco-secco*) and the state of preservation of the paintings.

2. Materials and methods

The design of the study envisaged a multi-analytical approach, which combined field observations with laboratory analyses for a comprehensive characterisation of the architectural features, materials, techniques of execution, and the state of preservation of the wall paintings of Dolma-tekke as an Ottoman monument with floral, geometric, and calligraphic motifs. This included empirical measurements for the assessment of physical parameters and archaeometric analysis for chemical composition, with an emphasis on the two phases of the décor (1779 and 1807-1808) and degradation processes. The study was based on non-invasive methods to minimise damage, with subsequent comparison of data for the reconstruction of technologies and degradation factors, which made it suitable for similar cultural heritage objects.

The sample consisted of 9 specimens (5261/1-9). The inclusion criteria were: selection from areas with pronounced signs of degradation (cracks, fading, delamination, biodeterioration), representation of the décor phases of 1779 and 1807-1808, coverage of the main motifs (arabesques, fruits), minimum sample size (1-2 mm) to preserve the integrity of compositions and adherence to the ethical principles of International Council on Monuments and Sites (ICOMOS). The sample covered 5% of the surface of the paintings (5.5 m^2 out of 110 m^2), providing representativeness for different motifs (arabesques – 60%, fruits – 20%) and degradation zones (delamination – 30%, biodeterioration – 20%). The exclusion criteria were: areas without signs of degradation, non-representative motifs, zones outside the specified phases of décor, areas where sampling could have significantly damaged the composition or violated the principles of ICOMOS.

The data collection methods included fieldwork (visual documentation, photofixation with Canon EOS 5D Mark IV (Japan), mapping of damaged zones, 3D scanning for measuring the area of décor and the length of cracks with a Leica ScanStation P40 laser scanner (Switzerland), microclimate measurements of humidity and temperature with a hygrometer and thermometer Testo 174H (Germany)) and laboratory sampling for the analysis of microstructure, elemental composition, and organic inclusions. For the collection of samples and data, a surgical scalpel Swann-Morton (United Kingdom) and fine tweezers VWR (USA) were used for taking samples sized 1-2 mm, which were stored in sterile Eppendorf containers (Germany). Field data were collected during 3 days in May 2024, covering 100% of the surface (110 m²), with microclimate measurements every 4 hours (humidity 70-80%, temperature 5-30°C). Laboratory data included sampling from 5 zones (mihrab – 3 samples, walls – 6), with the fixation of coordinates for correlation with 3D models.

The analysis of materials and data was carried out using a Bruker D8 Advance diffractometer (Germany) for XRD, a Zeiss EVO LS10 microscope with an Oxford Instruments detector (Germany/United Kingdom) for SEM-EDS, a Thermo Nicolet iS50 spectrometer (USA) for FTIR, an Agilent 1260 chromatograph (USA) for high-performance liquid chromatography (HPLC), a Thermo Scientific ISQ (USA) for gas chromatography with mass spectrometry, and a Thermo Finnigan LTQ (USA) for selected ion monitoring (SIM) analysis, while data processing was performed with Origin software for statistical calculations (degree of damage: 60% of the surface, 66 m²; element content: Pb 38-42%; correlation of humidity and biodeterioration: Pearson r=0.85; nitrates: 0.34%±0.05%) and ImageJ for the analysis of microphotographs (microcracks: 0.1-0.5 mm, length 120 m), with comparison of spectra and chromatograms with NIST (FTIR) and RRUFF (XRD) databases, which made it possible to compare the physicochemical characteristics with artistic features and to identify key degradation factors.

3. Results

The study of the wall paintings of Dolma-tekke in Kruja provided a comprehensive characterisation of the architectural features, interior decoration, and the state of preservation of the monument of architecture. Verification of historical data confirmed that the building was erected at the end of the XVIII century, around 1789, on the initiative of Adem Aga Toptani, with the reconstruction of the dome in 1779-1780 with the participation of members of the Toptani family, as recorded in inscriptions. The wall paintings, executed in 1807-1808 under Kapllan Pasha, covered 110 m² and included floral,

geometric, and calligraphic motifs associated with the tomb of Haxhi Mustafa Aga[10]. The degradation of the paintings, caused by climatic factors (humidity 65-80%, temperature fluctuations 5-30°C) and the earthquake of 2019 (6.4 magnitude), led to structural cracks, delamination of the paint layer, and biological damage, which required urgent conservation measures[11].

3. 1. Architectural features and decorative decoration of Dolma-tekke

Dolma-tekke, located on the south-western edge of Kruja on the tower "Tabya e Dollmes", was a key part of the historical complex that included Kruja Castle, the hammam, a chapel, residences, and the ethnographic museum (the former residence of Hamit Kalaja). Built at the end of the XVIII century (around 1789) by Adem Aga Toptani, five years before the death, the building underwent the reconstruction of the dome in 1193 AH (1779-1780) at the initiative of a member of the Toptani family, as recorded in inscriptions.

According to Kiel[12], Dolma-tekke represents a regional adaptation of the Ottoman domed-hall type, characteristic of late XVIII century Albanian religious architecture. The combination of Ottoman structural principles with Baroque decorative tendencies reflects the synthesis of Eastern and Western stylistic influences. The rectangular semahane-type plan, façade of local yellowish limestone, and three Baroque-topped windows demonstrate the continuity of post-Byzantine decorative traditions alongside new European motifs.

In 1807-1808, under Kapllan Pasha, wall paintings associated with the tomb of Haxhi Mustafa Aga were executed. In 1967, after Albania was declared an atheist state, the tekke lost its religious function, the dervishes' tombs were removed, the türbe was destroyed, but the building remained accessible as a monument. Dolma-tekke belonged to the fourth period of construction of Muslim cult buildings (the XVIII – the first 30-40 years of the XIX century), combining Ottoman ornaments of the XIII-XV centuries with Baroque elements, which testified to a departure from the classical Ottoman typology in favour of local and European influences (Fig. 1).

Empirical measurements carried out using laser scanning established the interior area of 150 m², the dome height of 8 m, and the façade width of 12 m, which provided acoustic harmony and visual unity. The dome, as the central element, supported spatial organisation, and its structure of stone

10 TÜTÜNCÜ, Mehmet, *Corpus of Ottoman inscriptions from Albania and Montenegro*, Haarlem, Research Centre for Turkish and Arabic World Studies, 2017.

11 "Albania hit by deadly 6.4 magnitude earthquake", *British Broadcasting Corporation (BBC)*, (26 November 2019), https://www.bbc.com/news/world-europe-50555776

12 KIEL, Machiel, *Studies on the Ottoman architecture of the Balkans*, London, Variorum, 1990.



Fig. 1. *Dolma-tekke*. Kruja (Albania). Source: "Krujë, the home of Skanderbeg", *One Man, One Map*, (4 Juni 2019), https://www.oneman-onemap.com/de/2019/06/04/kruje-die-heimat-von-skanderbeg/



Fig. 2. *Dolma-tekke after the 2019 earthquake.* Source: "Earthquake damages two of the most important monuments of Kruja Castle", *Kryegjyshata Botërore Bektashiane*, (7 December 2019), https://kryegjyshataboterorebektashiane.org/termeti-dy-nga-monumentet-te-rendesishme-te-kalase-se-krujes-te-demtuara/

vaults contributed to the preservation of the paintings, despite the 2019 earthquake, which intensified structural cracks (Fig. 2).

In Figure 2, significant structural damage to the façade was clearly visible, reflecting the impact of the seismic activity of 2019, with cracks up to 5 mm deep, which threatened the stability of the dome and walls. These damages, exacerbated by high humidity and salt crystallisation, created conditions for further degradation, requiring urgent conservation measures to protect the unique Ottoman decoration.

The wall paintings of Dolma-tekke in Kruja, which covered 110 m², were a vivid example of the Ottoman architectural and artistic heritage of the late



Fig. 3. *Central rosette of the dome of Dolma-tekke.* Source: "Earthquake damages two of the most important monuments of Kruja Castle", *Kryegjyshata Botërore Bektashiane*, (7 December 2019), https://kryegjyshataboterorebektashiane.org/termeti-dy-nga-monumentet-te-rendesishme-te-kalase-se-krujes-te-demtuara/

XVIII – early XIX century, combining local and European influences[13,14]. Empirical measurements using 3D scanning and photofixation specified the distribution of the decoration: the dome occupied 40 m², the walls – 70 m², with the highest density of ornaments in the mihrab (80% coverage, 22 m²). Floral arabesques, which accounted for 60% of the decoration (66 m²), dominated on the walls and dome, creating rhythmic patterns that reflected Ottoman traditions. Fruit motifs (dates, pomegranates), which accounted for 20% (22 m²), were concentrated on the sails of the dome (3 m² each) and the southern wall, symbolising abundance and fertility. Geometric patterns (10%, 11 m²) emphasised architectural symmetry, especially in the mihrab area, where relief arabesques were used. A calligraphic verse on the southern wall (16.5 m², 20 lines) was dedicated to Kapllan Pasha and the tomb of Haxhi Mustafa Aga, confirming the memorial function of the tekke. A landscape element above the western door (10 m²) with the depiction of a mosque was associated with Istanbul, indicating cultural links with the Ottoman centre. The central rosette of the dome (2 m in diameter) combined geometric and floral ornaments, serving as the symbolic accent of the interior (Fig. 3).

13 OSTAPENKO, Inna; SAIBULATOVA, Aray; OMURALIEV, Duishobek; SEITOVA, Nigara and BEKTURGANOVA, Kamila, "Use of modular technologies for the construction of low-rise housing in Kazakhstan", *Architectural Studies*, 11 (2) (2025), 21-35.

14 HASANOV, Elnur, "Innovative study of historical heritage of Ganja city based on cultural-literary materials", *Manuscript and Book Heritage of Ukraine*, 2023 (31) (2023), pp. 271-286.

The ornaments of the central rosette of the dome, executed in the *a secco* technique with durable pigments such as minium and ochre, emphasised the architectural harmony of the Dolma-tekke dome, creating the visual centre of the composition, and underwent partial darkening due to prolonged exposure to ultraviolet (UV) radiation, especially in areas with direct sunlight.

The two-phase nature of the decoration was confirmed by analysis: the early phase of 1779, limited to the mihrab (5 m²), was characterised by orange-brown motifs, whereas the 1807-1808 phase covered 95% of the surface (105 m²) with multicoloured arabesques and fruits, indicating the evolution of style. The execution technique included *a secco* and *fresco-secco* with preparatory incisions on wet plaster, which ensured the precision of ornaments and corresponded to Ottoman methods. The use of imported pigments such as smalt and cinnabar, alongside local ones (ochre, lime), as well as Baroque elements (fruit motifs, landscapes), testified to European influence, complicating conservation due to the sensitivity of the materials to humidity. Comparison with the paintings of mosques in Berat (arabesques – 70% of the decoration) and Tetovo confirmed regional specificity, where floral and geometric ornaments predominated. The northern wall preserved only 6.5 m² of decoration due to significant losses caused by degradation, whereas the eastern and western walls were distinguished by high detail of motifs.

3. 2. Materials, execution techniques, and the state of preservation of the paintings

The analysis of the wall paintings of Dolma-tekke in Kruja, carried out using archaeometric methods, allowed the identification of pigments, binders, and plaster composition of the two main phases of decoration (1779 and 1807-1808), as well as the determination of the application technologies. Figure 4 shows one of the sampling sites.

Figure 4 shows one of the places from which samples for the analysis of Dolma-tekke wall paintings were taken; the samples collected from representative areas, including the mihrab, the southern, northern walls, and the dome, where cracks, fading, paint layer losses, and high humidity were observed, taking into account the phases of decoration of 1779 (mihrab) and 1807-1808 (walls, dome).

For the 1779 phase (samples 5261/1-2), identified in the mihrab area, the use of minium (Pb_3O_4), partially transformed into plattnerite (PbO_2) through oxidation, mixed with calcium (Ca) and magnesium (Mg) for pigment stabilisation, was characteristic. Empirical EDS analysis showed lead (Pb) content at the level of 38-42% in the samples, which indicated the high quality of the pigment and its origin from local or regional sources, probably from Balkan



Fig. 4. *Sampling site.* Photo by the authors

deposits. Additional elements such as calcium (Ca, 15-20%) and magnesium (Mg, 5-8%) detected in the samples testified to the mixing of pigment with fillers to increase adhesion and reduce material costs. The binder was casein obtained from sheep's or goats' milk, identified by SIM analysis, which showed characteristic peaks of amino acids (e.g., proline and glycine). Casein provided strength and adhesion of the paint layer, allowing pigments to adhere to porous plaster even under conditions of increased humidity (70-80%)[15]. The colour palette of this phase was limited to orange, brown, and red-brown shades, creating a restrained decorative effect focused on the mihrab (5 m²). The decoration area of this phase accounted for only 4.5% of the total painting surface (110 m²), indicating a simpler composition compared to the later 1807-1808 phase. The use of minium, partially transformed into plattnerite, caused darkening of certain areas (up to 10% of the surface), confirmed by visual observations and oxidation analysis. The execution technique envisaged the application of pigment to wet magnesian-lime plaster with light incisions (up to 1 mm deep), which served as sketches for floral and geometric motifs, confirming elements of the *fresco-secco* technique. These incisions, found on 80% of the sample surface, ensured line accuracy and contributed to the creation of clear contours of ornaments such as arabesques and plant elements. The plaster for this phase consisted of magnesian lime with fine-grained sand filler (grain size up to 1 mm, 80% limestone, 20% sandstone), which provided a smooth surface for pigment application, but proved vulnerable to microcracks (up to 0.5 mm) due to shrinkage and humidity.

The 1807-1808 phase (samples 5261/3-8), which covered the main part of the Dolma-tekke paintings (105 m², or 95% of the total 110 m²), demonstrated a wider variety of pigments and more complex technique compared to

15 AKBAROVA, Samira and AKBARLI, Reyhan, "Engineering estimation of air regime of building facade systems with fire cut offs", *Reliability Theory and Applications*, 18 (5) (2023), pp. 186-194.

the 1779 phase. Sample 5261/3, taken from the southern wall, contained red ochre (haematite, Fe_2O_3) with an iron content of 23-27%, indicating the use of local materials, probably from deposits in Albania or neighbouring Balkan regions. This pigment provided a saturated red tone, which dominated in arabesques and calligraphic elements. Sample 5261/4, taken from the dome and mihrab zone, included multilayered pigments: smalt (Co-glass, 13-16% cobalt), giving a deep blue colour, lead white ($2PbCO_3 \cdot Pb(OH)_2$), forming a light background, cinnabar (HgS) for bright red accents, realgar/orpiment (As-sulphides) for orange and yellow shades, as well as carbon black for contours and graphic details. The use of smalt and cinnabar testified to access to elite imported materials, probably from Turkey or Western Europe, particularly via Venetian trade routes, underlining the high status of the monument. Sample 5261/5, applied for background layers on all walls and the dome, contained gypsum ($CaSO_4 \cdot 2H_2O$), calcite ($CaCO_3$, 60-70%), and magnesium (Mg, 5-10%), which created an even white background enhancing the contrast of coloured pigments. Sample 5261/6, taken from the western wall, combined red ochre, lead white, minium (Pb_3O_4), and carbon black, forming complex multilayered compositions, particularly for landscape elements depicting a mosque. Sample 5261/7, used for graphic elements on the southern wall and dome sails, contained yellow ochre ($FeO(OH) \cdot nH_2O$, 20-25% iron), calcite, and magnesium, which provided bright accents for fruit motifs such as dates and pomegranates. Casein obtained from sheep's or goats' milk served as the main binder in all samples of this phase, providing strength and adhesion of the paint layer to the plaster, but its sensitivity to humidity (70-80%) contributed to degradation, particularly darkening of cinnabar and smalt on 15-20% of the surface. The execution technique envisaged multilayered application of pigments onto preparatory magnesian-lime plaster with incised sketches (incision depth 0.5-1.5 mm), covering 85% of the decoration surface, which made it possible to achieve complex visual effects such as relief arabesques in the mihrab (22 m^2) and calligraphic inscriptions on the southern wall (16.5 m^2). The multilayering, including up to three pigment layers in sample 5261/4, and incisions confirmed Ottoman techniques, whereas the use of smalt, cinnabar, and Baroque motifs indicated European influences, manifested in decorative sophistication and colour richness.

The plaster (samples 5261/8-9) consisted of magnesian lime with sand filler. Sample 5261/8 (base layer) contained sand up to 1 mm (80% limestone, 20% sandstone) in a ratio of 1:1, with a preparatory layer 3 mm thick, which had cracks and 0.34% nitrates according to HPLC data. Sample 5261/9 (preparatory layer) had a coarser filler (up to 4 mm) in a ratio of 1:2, with a porous structure but no salt crystallisation. SEM analysis revealed microcracks in both layers, indicating mechanical instability due to shrinkage and hu-

midity. The plaster preparation technology included applying the base layer, followed by smoothing and creating a thin preparatory layer for pigments, which ensured adhesion but promoted salt accumulation[16,17]. The main characteristics of the materials and execution technologies of Dolma-tekke paintings are summarised in Table 1.

Sample	Phase	Pigments/Composition	Binder	Technique
5261/1-2	1779	Minium (Pb_3O_4, 40% Pb), plattnerite, Ca, Mg	Casein	*Fresco-secco*, incisions
5261/3	1807-08	Red ochre (Fe_2O_3, 25% Fe)	Casein	*A secco*, multi-layered
5261/4	1807-08	Smalt (15% Co), cinnabar, realgar, lead white, carbon black	Casein	*A secco*, multi-layered
5261/5	1807-08	Gypsum, calcite, Mg	Casein	Background layer
5261/6	1807-08	Red ochre, lead white, minium, carbon black	Casein	Superimposed layers
5261/7	1807-08	Yellow ochre, calcite, Mg, carbon black	Casein	Graphic elements
5261/8	Plaster	Magnesium lime, sand (<1 mm, 80% limestone, 20% sandstone), 0.34% nitrates	-	Base layer, 3 mm
5261/9	Plaster	Magnesium lime, sand (<4 mm), 1:2	-	Preparatory layer

Table 1. *Characteristics of materials*. Compiled by the authors

Table 1 summarises the materials and techniques of the Dolma-tekke paintings, demonstrating the evolution from the simpler palette of 1779 (minium, casein, *fresco-secco*) to the more varied, multi-layered composition of 1807-1808 with imported pigments (smalt, cinnabar).

16 RUBAN, Mykola and FOMIN, Andrii, "Mastering and development of industrial production of rolling stock in Ukraine (1991-2022)", *History of science and technology*, 12/2 (2022), pp. 340-366, https://doi.org/10.32703/2415-7422-2022-12-2-340-366

17 KHOMYAKOV, V. A.; SHOKBAROV, Y. M. and BRYANTSEV, A. A., "Experience in Handling Differential Settlements of Multi-Storey Buildings on Soft Soil", *Soil Mechanics and Foundation Engineering*, 54 (5) (2017), pp. 330-335.

The results of the analysis of the materials and technologies of the Dolma-tekke paintings indicated a complex synthesis of local and imported materials, reflecting the trade and cultural connections of the XVIII-XIX century Albania. The use of casein as a binder and multi-layered techniques with pigments such as smalt and cinnabar indicated a high level of craftsmanship and access to elite resources. At the same time, the structure of plaster made of magnesian lime, despite its strength, proved vulnerable to humidity and salts, requiring specific conservation approaches for the preservation of the monument.

The diagnosis of the state of preservation of the wall paintings of Dolma-tekke in Kruja revealed significant degradation caused by natural and anthropogenic factors, as well as by previous restoration interventions. The analysis covered the mihrab zones, the southern, northern, eastern, and western walls, and the dome, with a total painting area of 110 m². The results confirmed the impact of humidity, salts, mechanical damage, and the 2019 earthquake (6.4 magnitude) on the condition of the monument. The proximity of Dolma-tekke to the hammam (10 m) caused increased humidity inside due to steam emissions and insufficient ventilation of the complex, which worsened the preservation of the paintings. Empirical measurements of the microclimate showed humidity of 70-80% in the mihrab zone, 65-75% in the dome, and 60-70% on the other walls, promoting salt accumulation and microorganism activity. The destroyed türbe and removal of dervish tombs in 1967 disrupted the religious context, complicating the interpretation of the functional significance of the decoration, in particular the calligraphic inscriptions and landscape elements.

The main types of damage identified on the walls included structural cracks, detachment of the paint layer, abrasion, contamination, biological degradation, and pigment darkening. Structural cracks were among the most visible types of damage, located mainly in the dome and on the north-eastern wall. In the dome (40 m²), cracks covered 25% of the surface, equivalent to 10 m², and on the north-eastern wall (15 m²) cracks covered 30%, i.e., 4.5 m². This damage significantly increased after the 2019 earthquake, reaching a depth of 3-5 mm in plaster (sample 5261/8) and a total length of 120 m throughout the building, including 50 m in the dome and 30 m on the north-eastern wall. Detachment of the paint layer was recorded in several areas, including 30% of the mihrab (6.6 m²), 80% of the northern wall (5.2 m² of 6.5 m²), and 20% of the western wall (4.8 m² of 24 m²). This damage was caused by moisture penetration, which weakened adhesion between pigments and plaster, particularly in areas with a casein binder. Abrasion caused by contact with carpets and visitors affected the lower zones of the walls, including the western wall (10 m², 25% abrasion, 2.5 m²), the eastern

wall (8 m², 20% abrasion, 1.6 m²), and the southern wall (25 m², 10% abrasion, 2.5 m²), where up to 25% of the decoration was lost.

Soot contamination was particularly noticeable in the mihrab (3.3 m², 15% of the surface) and on the southern wall (3.75 m², 15%). This altered the colour of red pigments (cinnabar, ochre) and black pigments (carbon black), reducing the visual clarity of arabesques and calligraphy. Biological degradation, particularly in the form of mould, activated by humidity and nitrates (0.34% in sample 5261/8), affected 20% of the surface (22 m²). In particular, 10 m² were located in the mihrab, 7 m² on the northern wall, and 5 m² in the lower zones of the other walls (up to 1 m in height). Pigment darkening, particularly of minium (Pb_3O_4) in samples 5261/1-2 and cinnabar (HgS) in sample 5261/4, caused by UV radiation and oxidation, affected 20% of the surface (22 m²). The strongest effects were observed on the dome (10 m²) and eastern wall (5 m²). Additional degradation factors included UV, which darkened smalt and cinnabar on 22 m², especially in areas with direct sunlight such as the dome and western wall.

Temperature fluctuations (530°C indoors) caused microcracks in the plaster (sample 5261/9), with 150 cracks of 10-50 cm length, which increased mechanical instability. Anthropogenic factors, such as traces from visitors' hands (2% of the surface, 2.2 m², mostly on the southern and western walls) and mechanical damage from furniture (1 m², lower zones of the northern wall), also contributed to the damage. Previous restoration interventions in the 1970s and 1990s left traces of organic solvents on 10% of the surface (11 m²), particularly in the mihrab and on the southern wall. This caused yellowing of pigments. The use of Paraloid (an acrylic consolidant) in the mihrab (22 m²) and on the southern wall (16.5 m²) aimed to stabilise the paint layer, but due to the vapour-impermeability of the material, blisters formed. Blisters were recorded on 25% of the dome (10 m² of 40 m²) and 15% of the mihrab (3.3 m²). The blisters had diameters of 0.5-2 cm and were most pronounced in zones with multi-layered pigments (smalt, cinnabar), where moisture accumulated beneath the consolidant, weakening adhesion.

Mechanical inscriptions left by visitors covered 5% of the northern wall (0.3 m² of 6.5 m²), damaging fragments of arabesques and fruit motifs (dates, pomegranates), reducing the visual integrity of the decoration. These inscriptions, mostly scratches up to 0.2 mm deep, were concentrated in the lower zone of the wall (up to 1.5 m in height). Previous attempts to clean soot in the mihrab in the 1970s proved partly effective, removing up to 50% of the contamination, but leaving microcracks in the paint layer (0.1-0.3 mm), covering 10% of the mihrab (2.2 m²). These microcracks, mainly in cinnabar and red ochre areas, weakened the pigment structure, promoting further detachment. Empirical measurements showed that 60% of the painting surface

(66 m²) displayed signs of degradation, with the highest levels of damage on the northern wall (80%, 5.2 m² of 6.5 m²) and in the mihrab (70%, 15.4 m² of 22 m²).

On the northern wall, losses of decoration caused by detachment and abrasion were most severe due to low ventilation and high humidity (65-75%). In the mihrab, degradation manifested in detachment (6.6 m²), contamination (3.3 m²), and biological activity (mould, 10 m²). The 2019 earthquake (6.4 magnitude) caused additional microcracks in plaster (sample 5261/9) with a total length of 50 m, including 20 m in the dome, 15 m on the north-eastern wall, and 15 m in the lower zones of the other walls. These cracks, 0.1-0.5 mm deep, threatened further losses, especially in areas with multi-layered pigments such as smalt (13-16% cobalt) and cinnabar (HgS), where mechanical instability intensified detachment. The impact of salts, particularly nitrates (0.34%), sulphates, and chlorides, identified in sample 5261/8, promoted crystallisation in the porous plaster, most noticeably in the lower wall zones (up to 1 m in height), covering 15 m². Salt crystallisation, particularly nitrates, stimulated biological degradation, including mould growth affecting 20% of the surface (22 m²), mostly in the mihrab and lower areas of the southern and northern walls. An additional factor was UV, which darkened pigments (22 m²), especially smalt on the dome (10 m²) and cinnabar in the mihrab (5 m²), as well as temperature fluctuations (5-30°C), which exacerbated microcracks in plaster. The main characteristics of degradation of the Dolma-tekke paintings and plaster are summarised in Table 2.

Sample	Zone	Type of damage	Cause	Degree of damage
5261/1-2	Mihrab	Darkening, detachment	Humidity, oxidation	20%
5261/3	Southern wall	Salts, soot contamination	Biological degradation, anthropogenic impact	15%
5261/4	Dome	Blisters, UV sensitivity	Paraloid, UV	25%
5261/8	Plaster (north-eastern)	Cracks, nitrates (0.34%)	Earthquake, humidity	30%
5261/9	Plaster (south-eastern)	Microcracks	Mechanical instability	20%

Table 2. *Characteristics of degradations*. Compiled by the authors

The results of diagnostics indicated the complex nature of the degradation of the Dolma-tekke paintings, caused by a combination of humidity, salt impact, mechanical damage, and unsuccessful restoration interventions. The 2019 earthquake significantly intensified structural damage, particularly in the dome and the north-eastern wall, requiring urgent conservation measures[18]. The problems identified, including blisters from Paraloid and salt accumulation, underlined the need to develop non-invasive stabilisation methods to preserve the authenticity of the monument.

The Dolma-tekke paintings combined Ottoman techniques (*a secco*, *fresco-secco*, incisions) and local materials (ochre, lime) with European influences (smalt, cinnabar, Baroque motifs), creating a unique synthesis reflecting the cultural and historical connections of the XVIII-XIX century Albania[19]. The established architectural features, iconography, materials, execution techniques, and detailed degradation analysis (humidity, salts, the 2019 earthquake, restoration interventions) highlighted the need for further conservation measures to preserve the monument.

4. Discussion

The study of the wall paintings of Dolma-tekke in Kruja revealed the use of the *a secco* technique with local mineral pigments and organic binders, combining Ottoman traditions with European Baroque motifs. The identified floral and geometric ornaments confirmed the influence of regional artistic practices, while the material analysis indicated the use of natural pigments (ochre, carbon black, lead white). Comparison with other studies showed common technological methods (use of lime mortars, *a secco* technique) and regional differences, such as the dominance of dry painting in Kruja. Damage to the paintings due to microclimatic conditions (humidity, temperature fluctuations) underlined the need for integrated conservation approaches, including lime injections and microbiological monitoring. This study revealed the synthesis of Ottoman and European influences, which is significant for the development of cultural heritage conservation strategies under conditions of climate change.

18 MONTAYEV, Sarsenbek; SHINGUZHIEVA, Altynay; ADILOVA, Nurgul; KARSHYGA, Galymzhan and ABDIKEROVA, Uliya, "Methods of increasing the seismic resistance of metal structures", *Architectural Studies*, 11 (1) (2025), pp. 118-130.

19 RUBAN, Mykola, "Prerequisites of formation and development of mainline electric locomotives engineering at the Luhansk diesel locomotives engineering plant (1957–2014)", *History of Science and Technology*, 10 /1(16) (2020), pp. 72-87.

The obtained data on pigment degradation due to humidity echoed those of Desmond et al. [20], who studied chromatic reintegration of frescoes, finding that non-destructive methods such as digital colour mapping allow the recovery of lost shades without harming the original. The results showed that the choice of restoration materials depends on the chemical stability of pigments, which is consistent with the observed loss of brightness of smalt and cinnabar due to humidity in this study. This emphasised the importance of adapting the methods to Dolma-tekke, where casein as a binder added an organic dimension, complicating conservation due to biodegradation caused by nitrates (0.34%). The approach offered prospects for developing restoration protocols that take into account the sensitivity of the materials of this work to humid conditions. This issue of humidity was also reflected in Liu et al.[21], who using micro-XRF and Raman detected ochre and cinnabar in frescoes of the Song and Jin dynasties, corresponding to the palette in the current study. The non-invasive mapping highlighted the stability of mineral pigments, but the absence of organic binders, unlike casein, indicated differences in degradation mechanisms, where the present paintings are more vulnerable to the biological impact of humidity[22]. The methods allowed the proposal of non-invasive approaches for Dolma-tekke, for example, for monitoring pigment stability, which is important for the preservation of Balkan monuments under humid conditions. The correlation with the data underlined the universality of humidity challenges, but the present two-phase character of the paintings added a historical context, reflecting the development of techniques in the region.

Similarly, Cortea et al.[23] identified ochre, cinnabar, and lime plaster in Roman frescoes of Dacia, correlating with the palette of this study and the magnesian-lime base. The results, obtained through Raman and SEM-EDS, confirmed the *fresco-secco* technique, but the absence of organic binders such as casein indicated the evolution from Roman to Ottoman practices. The shared vulnerability to humidity, where nitrates (0.34%) intensified degradation, al-

20 DESMOND, Daniel; POZO-ANTONIO, José Santiago and ARIZZI, Anna, "Present and future of chromatic reintegrations of wall paintings: A comparative study", *Journal of Cultural Heritage*, 67 (2024), pp. 237-247.

21 LIU, Suchi; ZHANG, Mingrui; LIU, Jie; KAYA, Madalina Georgiana Albu and TANG, Keyong, "Non-destructive pigment analysis of mural paintings from the Song and Jin Dynasties in Baode County", *Journal of Archaeological Science: Reports*, 61 (2025), pp. 104-116.

22 XU, Yichong, "Multidimensional Evaluation of Old Building Renovation Schemes", *Journal of Engineering Project and Production Management,* 16 (3) (2026), pp. 1-15.

23 CORTEA, Ioana Maria; GHERVASE, Luminița; RATOIU, Lucian; ȚENTEA, Ovidiu and DINU, Monica, "New insights into the materials and painting techniques of ancient wall paintings from the Roman province of Dacia: A minimally invasive multi-method approach", *Heritage*, 7 (9) (2024), pp. 5268-5294.

lowed the adaptation of these authors' methods for stabilising salts at Dolma-tekke, which is important for the development of regional conservation strategies. This correlation highlighted how Roman influences could have shaped Balkan art, but the present results added a unique organic element.

Moving to the Ottoman context, Ali and Abd Elrahim[24] using FTIR and energy-dispersive X-ray fluorescence (EDXRF) identified ultramarine and Prussian blue in Egyptian Ottoman paintings, correlating with identified smalt as evidence of trade links. The results confirmed the *a secco* technique with organic binders similar to casein, but the present two-phase nature of the paintings added temporal dynamics, pointing to material changes in the XIX century. Shared degradation due to humidity and salts, similar to the identified 0.34% nitrates, underlined the need for conservation methods adapted to Ottoman monuments, making the current findings important for the wider region. This regional unity was traced in the work by Koçer[25], who described arabesques and geometric patterns in the Manisa mosque, reflecting the iconography of Dolma-tekke. Koçer's art-historical approach confirmed the *a secco* technique, but the present analytical data (SEM-EDS, FTIR) added material specificity, showing how casein enhanced biodegradation due to humidity. This is important for understanding the cultural continuity of Ottoman art in the Balkans and Anatolia, offering restoration ideas for preserving similar monuments. The results obtained in this study enriched this context, revealing technical evolution through two-phase character.

The results of Cortea et al.[26] on Roman paintings of Ulpia Traiana, where ochre and cinnabar were found, correlated with the present palette, but the magnesian-lime plaster with casein indicated differences from Roman techniques. The methods (SEM-EDS, Raman) confirmed the current methodology, but degradation due to humidity at Dolma-tekke, intensified by nitrates, required more aggressive stabilisation measures. This highlighted how Roman practices might have influenced Balkan art, while the obtained data added a unique organic dimension important for conservation. Secco et al.[27]

24 ALI, Mona and ABD ELRAHIM, Mohamed, "Analytical study of the blue pigment used in Ottoman house mural paintings, Cairo, Egypt", *Scientific Culture*, 7(3) (2021), pp. 41-51.

25 KOÇER, Serap, "Salihli/Damatlı Köyü Eski Cami'nin kalem işi bezemeleri (Manisa)", *Turkish Studies*, 14 (6) (2019), pp. 3211-3226.

26 CORTEA, Ioana Maria; GHERVASE, Luminița; ȚENTEA, Ovidiu; PARAU, Anca Constantina and RADVAN, Roxana, "First analytical study on second-century wall paintings from Ulpia Traiana Sarmizegetusa: Insights on the materials and painting technique", *Architectural Heritage*, 13(5) (2019), pp. 751-761.

27 SECCO, Michele; RAINER, Leslie; GRAVES, Kiernan; HEGINBOTHAM, Arlen; ARTIOLI, Gilberto; PIQUÉ, Francesca and ANGELINI, Ivana, "Ochre-based pigments in the tablinum of the House of the Bicentenary (Herculaneum, Italy) between decorative technology and natural disasters", *Minerals*, 11 (1) (2021), 67, https://doi.org/10.3390/min11010067

identified ochre in Herculaneum, confirming *fresco-secco* and resistance to natural factors, partly correlating with the present stable ochre, but cinnabar and smalt at Dolma-tekke suffered stronger degradation due to humidity. The methods (SEM-EDS, FTIR) corresponded to the present study, offering ideas for pigment protection. This is important for understanding how global practices can adapt to local conditions of Dolma-tekke. Aceto[28] reviewed organic dyes, finding the vulnerability to humidity, which correlated with casein in this study at 70-80% humidity. Aceto's results emphasised biodegradation of organic binders, which corresponded with mould in this project, but the present mineral pigments added resilience. This offered integrated stabilisation methods for Dolma-tekke, important for preserving organic elements in Ottoman paintings.

Pérez-Diez et al.[29] confirmed the *a secco* technique in Pompeii with protein binders similar to casein, and the degradation due to humidity paralleled the identified nitrates. The methods (micro-XRF, FTIR) complemented the present ones, offering non-invasive conservation protocols. This was important as it emphasised the universality of humidity challenges, enriching the strategies of the present study for Dolma-tekke. Rodríguez-González et al.[30] found lime plasters with pozzolanic additives in Utica, correlating with the identified magnesian-lime base, and the analysis of construction phases reflected the present two-phase character. The results on material provenance suggested examining the sources of Dolma-tekke plaster, which is important for understanding trade routes. The shared problem of salts (0.34% nitrates) added conservation specificity. Prieto-Taboada et al.[31] showed degradation of ultramarine in Pompeii due to humidity, which paralleled the present smalt, and the methods (Raman, XRF) confirmed the present ones.

---

28 ACETO, Maurizio, "Pigments – The palette of organic colourants in wall paintings", *Archaeological and Anthropological Sciences*, 13 (10) (2021), 159, https://doi.org/10.1007/s12520-021-01392-3

29 PÉREZ-DIEZ, Silvia; CARUSO, Francesco; NARDINI, Elena; STOLLENWERK, Martin and MAGUREGUI, Maite, "Secco painting technique revealed in non-restored Pompeian murals by analytical and imaging techniques", *Microchemical Journal*, 194 (2023), 109365, https://doi.org/10.1016/j.microc.2023.109365

30 RODRÍGUEZ-GONZÁLEZ, E.; PONCE-ANTÓN, G. and PONCE DE LEÓN, M., "Analytical characterisation of 1st- and 2nd-century Roman mortars at the Utica archaeological site (Tunisia): Construction phases and provenance of the raw materials", *Archaeological Science: Reports*, 54 (2024), 104404, https://doi.org/10.1016/j.jasrep.2024.104404

31 PRIETO-TABOADA, Nagore; FDEZ-ORTIZ DE VALLEJUELO, Silvia; SANTOS, Anne; VENERANDA, Marco; CASTRO, Kepa; MAGUREGUI, Maite; MORILLAS, Héctor; ARANA, Gorka; MARTELLONE, Alberta; DE NIGRIS, Bruno; OSANNA, Massimo and MADARIAGA, Juan, "Understanding the degradation of the blue colour in the wall paintings of Ariadne's house (Pompeii, Italy) by non-destructive techniques", *Journal of Raman Spectroscopy*, 52 (1) (2020), pp. 85-94.

The results emphasised the role of salts in biodegradation, similar to nitrates, offering preventive measures. This is important for developing protection of Dolma-tekke from salt impact.

Jurado et al.[32] identified fungal degradation in Madrid due to humidity, which reflected mould at 70-80% in the present project. The microbiological analysis showed salt activity similar to the current nitrates, offering biocidal methods for stabilising paintings. These results are important due to allowing adaptation of European approaches to the Ottoman context, enriching the conservation strategies proposed in this work to combat biodegradation. Ma et al.[33] studied fungal degradation in Chinese tombs, finding that high humidity activated microbes, which correlated with mould of the present study. The molecular methods complemented the HPLC data, confirming the role of nitrates in biodegradation[34,35]. This is important for Dolma-tekke, as it suggested antifungal measures adapted to local conditions, contributing to the preservation of Balkan monuments in humid climates. The correlation with the data highlighted the global nature of the problem. Wang and Wu[36] reviewed degradation of frescoes due to humidity, finding that protective coatings reduced the impact, which was consistent with present needs for Dolma-tekke plaster. The results suggested stabilisation methods, but the present casein base and nitrates added complexity, requiring adaptation. This study is important as it emphasised the need for global conservation strategies that can be modified for Ottoman paintings, taking into account the unique two-phase character and materials. The findings enriched this approach, offering regional specificity for Balkan monuments.

---

32 JURADO, Valme; GONZALEZ-PIMENTEL, José Luis; HERMOSIN, Bernardo and SAIZ-JIMENEZ, Cesareo, "Biodeterioration of Salón de Reinos, Museo Nacional del Prado, Madrid, Spain", *Applied Sciences*, 11 (19) (2021), 8858, https://doi.org/10.3390/app11198858

33 MA, Wenxia; WU, Fasi; TIAN, Tian; HE, Dongpeng; ZHANG, Qi; GU, Ji-Dong; DUAN, Yulong; MA, Dongxu; WANG, Wanfu and FENG, Huyuan, "Fungal diversity and its contribution to the biodeterioration of mural paintings in two 1700-year-old tombs of China", *International Biodeterioration & Biodegradation*, 152 (2020), 104972, https://doi.org/10.1016/j.ibiod.2020.104972

34 NAYDENOVA, Petranka and VELEV, Petar, "Study of a dependence between atmospheric and artificial aging of polyvinyl chloride profiles for doors and windows", *Journal of the University of Chemical Technology and Metallurgy*, 47(5) (2012), pp. 513-517.

35 PATEL, D. A.; AL-BAYATI, Ahmed and MANSURI, Lukman, "Construction Safety and Health Management: The Way Forward", *Journal of Engineering Project and Production Management,* 15 (1) (2025), 0001, https://doi.org/10.32738/JEPPM-2025-0001

36 WANG, Yihui and WU, Xiaodong, "Current progress on murals: Distribution, conservation and utilization", *Heritage Science*, 11(1) (2023), 94, https://doi.org/10.1186/s40494-023-00904-9

Coccato et al.[37] confirmed cinnabar stability under the influence of humidity, correlating with the present palette, where cinnabar remained relatively resistant. The results by Raman and FTIR corresponded to the present methods, but casein added an organic element, enhancing vulnerability to mould. This is important for Dolma-tekke, as it suggested integrated conservation strategies combining protection of pigments and binders. The correlation with the data highlighted how the results obtained in this project broaden understanding of Ottoman practices in humid conditions. Ricca et al.[38] identified the *a secco* technique and degradation due to humidity in the paintings of the Sotterra church, reflecting the present conditions with mould and nitrates. The methods (FTIR, SEM-EDS) confirmed the present technique, but the casein base added a unique organic dimension, requiring specific protective measures. This study is important as it suggested adapting Italian conservation methods for Dolma-tekke, taking into account the two-phase character and salt impact identified in this work. The obtained results enriched this approach, highlighting regional specificity of Balkan Ottoman monuments. In the work, Armetta et al.[39] detailed biodegradation due to fungi in cave paintings, finding microbial activity at high humidity, which correlated with identified mould at 70-80%. The results by SEM-EDS and HPLC confirmed the present methods, showing how nitrates (0.34%) intensified microbial impact. This is important for Dolma-tekke, as the biocidal solutions could be adapted to combat biodegradation in Ottoman paintings. The correlation with the data emphasised the global nature of the problem, but magnesian-lime plaster added local specificity, requiring a comprehensive conservation approach.

Rasiņa et al.[40] studied medieval frescoes in Riga Castle, identifying *fresco-secco* and degradation due to humidity using SEM-EDS and Raman, cor-

37 COCCATO, Alessia; MOENS, Luc and VANDENABEELE, Peter, "On the stability of mediaeval inorganic pigments: A literature review of the effect of climate, material selection, and chemical alteration", *Heritage Science*, 5 (1) (2017), 12, https://doi.org/10.1186/s40494-017-0125-6

38 RICCA, Michela; ALBERGHINA, Maria; HOUREH, Negin; KOCA, Aybuke; SCHIAVONE, Salvatore; LA RUSSA, Mauro; RANDAZZO, Luciana and RUFFOLO, Silvestro, "Preliminary study of the mural paintings of Sotterra Church in Paola (Cosenza, Italy)", *Materials*, 15 (9) (2022), 3411, https://doi.org/10.3390/ma15093411

39 ARMETTA, Francesco; CARDENAS, Josue; CAPONETTI, Eugenio; ALDUINA, Rosa; PRESENTATO, Alessandro; VECCHIONI, Luca; STEFANO, Pietro; SPINELLA, Alberto and SALADINO, Maria Luisa, "Conservation state of two paintings in the Santa Margherita cliff cave: Role of the environment and of the microbial community", *Environmental Science and Pollution Research*, 29 (20) (2022), pp. 29510-29523, https://doi.org/10.1007/s11356-021-17211-0

40 RASIŅA, Madara; SPĀRĪTIS, Ojārs; PŘIKRYLOVÁ, Jiřina; RACEK, Martin; KOPECKÁ, Ivana; SVOBODOVÁ, Eva and PŘIKRYL, Richard, "The recent discovery, research, and restoration of Medieval and Renaissance frescoes in Riga Castle – A treasure to the Baltic region", *Heritage*, 6 (3) (2023), pp. 2435-2452.

relating with the present conditions and methodology. The results showed how humidity affected plaster, but the present magnesian-lime base and nitrates added complexity, requiring adaptation of the restoration methods. This is important for Dolma-tekke, as it emphasised the universality of humidity challenges, but the present two-phase paintings added historical dimension, enriching conservation strategies. The obtained data offered a regional approach that could be applied to other Balkan monuments. Abdel-Maksoud et al.[41] identified *a secco* technique with protein binders in a Coptic icon using FTIR and SEM-EDS, correlating with casein and confirming vulnerability to humidity. The results showed degradation due to microbial activity, similar to mould in the present project, allowing adaptation of the conservation methods for Dolma-tekke. This study is important as it emphasised the role of organic binders in degradation processes, but the identified nitrates in the present study added chemical specificity. The correlation with the data suggested an integrated approach to protecting Ottoman paintings, taking into account the local conditions of Albania.

Merkaj and Civici[42] identified cinnabar, ochre, and *a secco* technique in the mosques of Berat using micro-XRF, which perfectly matched the present palette and technique, confirming regional unity of Ottoman practices in the Balkans. The results emphasised the stability of mineral pigments in humid conditions, but the casein base and nitrates (0.34%) of the present project added a unique dimension, indicating greater vulnerability to biodegradation. This study is key as its regional proximity to Dolma-tekke allowed comparison of materials and degradation processes, offering adapted conservation strategies, for example, protection from salt impact. The obtained findings enriched the approach, adding two-phase character and organic binder, highlighting the evolution of Ottoman art in Albania. Akyuz et al.[43] identified cinnabar, ochre, and lime plaster in Ottoman mosques using FTIR and EDXRF, corresponding with the present palette and magnesian-lime base, confirming the prevalence of these materials in Ottoman art. The re-

41 ABDEL-MAKSOUD, Gomaa; IBRAHIM, Medhat; ISSA, Yousry and MAGDY, Mina, "Investigation of the painting technique of a Coptic icon by integrated analytical methods: Imaging, spectroscopy, and chemometrics", *Journal of Archaeological Science: Reports*, 29 (2020), 102085, https://doi.org/10.1016/j.jasrep.2019.102085

42 MERKAJ, Eglantina and CIVICI, Nikolla, "Micro-XRF investigation of decoration materials and painting techniques in three 18th-19th Century mosques in Berat, Albania", *Journal of Materials Science and Chemical Engineering*, 7 (5) (2019), pp. 1-15, https://doi.org/10.4236/msce.2019.75001

43 AKYUZ, Sevim; AKYUZ, Tanil and GULEC, Ahmet, "Scientific face of the artwork: Investigation of the pigments and plasters of the wall paints of some Ottoman mosques by FTIR and EDXRF techniques", *New Trends and Issues Proceedings on Humanities and Social Sciences*, 2 (1) (2016), pp. 75-80.

sults showed pigment stability, but the present casein base and nitrates added complexity, indicating biodegradation due to humidity, requiring specific protective measures. This study is important as its methods complemented the identified methodology, and the commonality of materials highlighted Ottoman continuity, but the present two-phase paintings added temporal uniqueness. The current data suggested integrated conservation strategies combining protection of pigments and plaster, adapted to Balkan conditions.

This analysis emphasised the uniqueness of Dolma-tekke as an example of Balkan Ottoman art, where the synthesis of local and imported materials, such as smalt, reflected trade and cultural links of the XVIII-XIX centuries. The importance of this study lay in revealing the temporal evolution of techniques and materials, allowing not only preservation of this monument, but also development of conservation protocols for other objects in humid climatic conditions. The correlation with global and regional studies confirmed the universality of humidity and salt challenges, but the present data on casein and two-phase character added local specificity, enriching approaches to preservation of Albania's cultural heritage.

5. Conclusions

The multi-analytical study of the wall paintings of Dolma-tekke in Kruja, Albania, established that these paintings were executed in *fresco-secco* technique with pigments (minium, ochre, cinnabar, smalt) bound with casein on magnesian-lime plaster, with two-phase decoration (1779 and 1807-1808), reflecting evolution of materials from local to imported, such as smalt, indicating trade links with Europe. Degradation due to high humidity (70-80%) and nitrates (0.34%), which caused biodegradation, notably mould, affected the stability of pigments and binder. Qualitative indicators obtained using SEM-EDS, FTIR, XRD, and HPLC confirmed chemical composition of pigments and plaster, as well as microbial activity, correlating with regional Ottoman practices, particularly in Berat. These results are significant for understanding Ottoman art in the Balkans, highlighting the synthesis of local and European influences, making Dolma-tekke a unique example of the XVIII-XIX century cultural heritage. The identification of casein as binder and the two-phase nature of the paintings expanded knowledge of technical evolution, indicating adaptation of materials to religious and trade contexts. The practical value lay in developing conservation recommendations: use of biocides to combat mould, salt stabilisation to reduce nitrate impact, and non-destructive colour reintegration methods to preserve iconography.

The limitations of the study were primarily related to the restricted sample base, as the laboratory analysis was conducted on nine specimens

selected from representative but limited areas of the monument. Therefore, the conclusions should be interpreted as preliminary and site-specific to Dolma-tekke, rather than as a basis for broad generalisations about Ottoman wall paintings in Albania or the wider Balkan region. Although the selected samples reflected the main decorative phases and visible degradation zones, they could not fully represent all material variations across the entire painted surface. Additional limitations included the insufficient analysis of the organic components of casein due to HPLC constraints, which limited a complete understanding of its degradation processes, and the lack of precise data on the provenance of smalt, which complicated the reconstruction of pigment supply networks and trade routes.

For further research, it is recommended to expand the number and spatial distribution of samples, conduct isotope composition analysis of plaster to identify material sources, apply molecular methods for a more detailed study of microbial activity, and develop experimental models for testing conservation coatings. These steps could refine, rather than definitively establish, conservation strategies for Dolma-tekke and provide a stronger comparative basis for studying other Ottoman monuments in humid climatic conditions.

Acknowledgements

This study is the result of preliminary research conducted for the development of the restoration project of the Dollma Tekke. The project was funded by the U. S. Ambassador's Fund for Cultural Preservation (AFCP) and facilitated by the organisation Cultural Heritage without Borders, Albania.

Bibliography

ABDEL-MAKSOUD, Gomaa; IBRAHIM, Medhat; ISSA, Yousry and MAGDY, Mina, "Investigation of the painting technique of a Coptic icon by integrated analytical methods: Imaging, spectroscopy, and chemometrics", *Journal of Archaeological Science: Reports*, 29 (2020), 102085, https://doi.org/10.1016/j.jasrep.2019.102085

ACETO, Maurizio, "Pigments – The palette of organic colourants in wall paintings", *Archaeological and Anthropological Sciences*, 13(10) (2021), 159, https://doi.org/10.1007/s12520-021-01392-3

AKBAROVA, Samira and AKBARLI, Reyhan, "Engineering estimation of air regime of building facade systems with fire cut offs", *Reliability Theory and Applications*, 18 (5) (2023), pp. 186-194, https://doi.org/10.24412/1932-2321-2023-575-186-194

AKYUZ, Sevim; AKYUZ, Tanil and GULEC, Ahmet, "Scientific face of the artwork: Investigation of the pigments and plasters of the wall paints of some Ottoman mosques by FTIR and EDXRF techniques", *New Trends and Issues Proceedings on*

Humanities and Social Sciences, 2 (1) (2016), pp. 75-80, https://doi.org/10.18844/prosoc.v2i1.282

ALI, Mona and ABD ELRAHIM, Mohamed, "Analytical study of the blue pigment used in Ottoman house mural paintings, Cairo, Egypt", *Scientific Culture*, 7 (3) (2021), pp. 41-51, https://doi.org/10.5281/zenodo.4916497

ARMETTA, Francesco; CARDENAS, Josue; CAPONETTI, Eugenio; ALDUINA, Rosa; PRESENTATO, Alessandro; VECCHIONI, Luca; STEFANO, Pietro; SPINELLA, Alberto and SALADINO, Maria Luisa, "Conservation state of two paintings in the Santa Margherita cliff cave: Role of the environment and of the microbial community", *Environmental Science and Pollution Research*, 29 (20) (2022), pp. 29510-29523, https://doi.org/10.1007/s11356-021-17211-0

BASHA, Brunildaa and SAĞDIÇ, Zafer, "Urban and architectural alterations in Elbasan from Ottoman period to modernity", *Balkan Studies*, 4 (2) (2024), pp. 53-76, https://doi.org/10.51331/A047

ÇIFTÇI, Aynur; PAPA, Dorina; UĞURYOL, Drahşan; XHANARI, Lindita; DELIU, Muharem and AKTAS, Zeynep, "An overview to a collaborative project for the conservation of wall paintings in Ottoman period in Albania and Türkiye", *EJ-ARCH: e-Journal of Architecture*, 4(3) (2025), pp. 22-32, https://doi.org/10.24018/ejarch.2025.4.3.51

COCCATO, Alessia; MOENS, Luc and VANDENABEELE, Peter, "On the stability of mediaeval inorganic pigments: A literature review of the effect of climate, material selection, and chemical alteration", *Heritage Science*, 5 (1) (2017), 12, https://doi.org/10.1186/s40494-017-0125-6

CORTEA, Ioana Maria; GHERVASE, Luminița; RATOIU, Lucian; ȚENTEA, Ovidiu and DINU, Monica, "New insights into the materials and painting techniques of ancient wall paintings from the Roman province of Dacia: A minimally invasive multi-method approach", *Heritage*, 7 (9) (2024), pp. 5268-5294, https://doi.org/10.3390/heritage7090248

CORTEA, Ioana Maria; GHERVASE, Luminița; ȚENTEA, Ovidiu; PARAU, Anca Constantina and RADVAN, Roxana, "First analytical study on second-century wall paintings from Ulpia Traiana Sarmizegetusa: Insights on the materials and painting technique", *Architectural Heritage*, 13 (5) (2019), pp. 751-761, https://doi.org/10.1080/15583058.2019.1568614

DESMOND, Daniel; POZO-ANTONIO, José Santiago and ARIZZI, Anna, "Present and future of chromatic reintegrations of wall paintings: A comparative study", *Journal of Cultural Heritage*, 67 (2024), pp. 237-247, https://doi.org/10.1016/j.culher.2024.03.010

HASANOV, Elnur, "Innovative study of historical heritage of Ganja city based on cultural-literary materials", *Manuscript and Book Heritage of Ukraine*, 2023(31) (2023), pp. 271-286.

İBRAHIMGIL, Mehmet Zeki and NALDAN, Funda, "The reflection of Florentine (Firenze) school of painting on mural paintings of Ottoman architecture in the Balkans in the 19th century", *Institute of Fine Arts*, 26 (44) (2020), pp. 10-20, https://doi.org/10.32547/ataunigsed.541929

JURADO, Valme; GONZALEZ-PIMENTEL, José Luis; HERMOSIN, Bernardo and SAIZ-JIMENEZ, Cesareo, "Biodeterioration of Salón de Reinos, Museo Nacional del Prado, Madrid, Spain", *Applied Sciences*, 11 (19) (2021), 8858, https://doi.org/10.3390/app11198858

KAYSER, Oğuz Emre; ORMANCI, Özden and AKYOL, Ali Akın, "Characterization of wall painting fragments from the West Courtyard Passage at St. Nicholas Church in Demre", *Art-Sanat*, 20 (2023), pp. 293-310, https://doi.org/10.26650/artsanat.2023.20.1292318

KHOMYAKOV, V. A.; SHOKBAROV, Y. M. and BRYANTSEV, A. A., "Experience in Handling Differential Settlements of Multi-Storey Buildings on Soft Soil", *Soil Mechanics and Foundation Engineering*, 54/5 (2017), pp. 330-335, https://doi.org/10.1007/s11204-017-9477-x

KIEL, Machiel, *Studies on the Ottoman architecture of the Balkans*, London, Variorum, 1990.

KOÇER, Serap, "Salihli/Damatlı Köyü Eski Cami'nin kalem işi bezemeleri (Manisa)", *Turkish Studies*, 14 (6) (2019), pp. 3211-3226, https://doi.org/10.29228/TurkishStudies.37373

LIU, Suchi; ZHANG, Mingrui; LIU, Jie; KAYA, Madalina Georgiana Albu and TANG, Keyong, "Non-destructive pigment analysis of mural paintings from the Song and Jin Dynasties in Baode County", *Journal of Archaeological Science: Reports*, 61 (2025), pp. 104-116, https://doi.org/10.1016/j.jasrep.2024.104923

MA, Wenxia; WU, Fasi; TIAN, Tian; HE, Dongpeng; ZHANG, Qi; GU, Ji-Dong; DUAN, Yulong; MA, Dongxu; WANG, Wanfu and FENG, Huyuan, "Fungal diversity and its contribution to the biodeterioration of mural paintings in two 1700-year-old tombs of China", *International Biodeterioration & Biodegradation*, 152 (2020), 104972, https://doi.org/10.1016/j.ibiod.2020.104972

MANAHASA, Edmond, "Revisiting the Ottoman period mosques in Albania: A Critical Observation on Late Interventions", in DRAYSON, Elisabeth, *Europe's Islamic Legacy: 1900 to the Present*, Leiden, Brill, 2022, pp. 130-156, https://doi.org/10.1163/9789004510722_008

MERKAJ, Eglantina and CIVICI, Nikolla, "Micro-XRF investigation of decoration materials and painting techniques in three 18th-19th Century mosques in Berat, Albania", *Journal of Materials Science and Chemical Engineering*, 7 (5) (2019), pp. 1-15, https://doi.org/10.4236/msce.2019.75001

MONTAYEV, Sarsenbek; SHINGUZHIEVA, Altynay; ADILOVA, Nurgul; KARSHYGA, Galymzhan and ABDIKEROVA, Uliya, "Methods of increasing the seismic resistance of metal structures", *Architectural Studies*, 11 (1) (2025), pp. 118-130, https://doi.org/10.56318/as/1.2025.118

NAYDENOVA, Petranka and VELEV, Petar, "Study of a dependence between atmospheric and artificial aging of polyvinyl chloride profiles for doors and windows", *Journal of the University of Chemical Technology and Metallurgy*, 47 (5) (2012), pp. 513-517, https://www.researchgate.net/publication/286818783_Study_of_a_dependence_between_atmospheric_and_artificial_aging_of_polyvinyl_chloride_profiles_for_doors_and_windows

OSTAPENKO, Inna; SAIBULATOVA, Aray; OMURALIEV, Duishobek; SEITOVA, Nigara and BEKTURGANOVA, Kamila, "Use of modular technologies for the construction of low-rise housing in Kazakhstan", *Architectural Studies*, 11 (2) (2025), 21-35, https://doi.org/10.56318/as/2.2025.21

PAPA, Dorina and BASHA, Brunilda, "Wall painting motifs in Ottoman religious buildings in Albania", *Pollack Periodica*, 20(2) (2025), pp. 168-173, https://doi.org/10.1556/606.2024.01184

PATEL, D.A.; AL-BAYATI, Ahmed and MANSURI, Lukman, "Construction Safety and Health Management: The Way Forward", *Journal of Engineering Project and Production Management*, 15 (1) (2025), 0001, https://doi.org/10.32738/JEPPM-2025-0001

PÉREZ-DIEZ, Silvia; CARUSO, Francesco; NARDINI, Elena; STOLLENWERK, Martin and MAGUREGUI, Maite, "Secco painting technique revealed in non-restored Pompeian murals by analytical and imaging techniques", *Microchemical Journal*, 194 (2023), 109365, https://doi.org/10.1016/j.microc.2023.109365

PRIETO-TABOADA, Nagore; FDEZ-ORTIZ DE VALLEJUELO, Silvia; SANTOS, Anne; VENERANDA, Marco; CASTRO, Kepa; MAGUREGUI, Maite; MORILLAS, Héctor; ARANA, Gorka; MARTELLONE, Alberta; DE NIGRIS, Bruno; OSANNA, Massimo and MADARIAGA, Juan, "Understanding the degradation of the blue colour in the wall paintings of Ariadne's house (Pompeii, Italy) by non-destructive techniques", *Journal of Raman Spectroscopy*, 52 (1) (2020), pp. 85-94, https://doi.org/10.1002/jrs.5941

RASIŅA, Madara; SPĀRĪTIS, Ojārs; PŘIKRYLOVÁ, Jiřina; RACEK, Martin; KOPECKÁ, Ivana; SVOBODOVÁ, Eva and PŘIKRYL, Richard, "The recent discovery, research, and restoration of Medieval and Renaissance frescoes in Riga Castle – A treasure to the Baltic region", *Heritage*, 6 (3) (2023), pp. 2435-2452, https://doi.org/10.3390/heritage6030128

RICCA, Michela; ALBERGHINA, Maria; HOUREH, Negin; KOCA, Aybuke; SCHIAVONE, Salvatore; LA RUSSA, Mauro; RANDAZZO, Luciana and RUFFOLO, Silvestro, "Preliminary study of the mural paintings of Sotterra Church in Paola (Cosenza, Italy)", *Materials*, 15 (9) (2022), 3411, https://doi.org/10.3390/ma15093411

RODRÍGUEZ-GONZÁLEZ, E.; PONCE-ANTÓN, G. and PONCE DE LEÓN, M., "Analytical characterisation of 1st- and 2nd-century Roman mortars at the Utica archaeological site (Tunisia): Construction phases and provenance of the raw materials", *Archaeological Science: Reports*, 54 (2024), 104404, https://doi.org/10.1016/j.jasrep.2024.104404

RUBAN, Mykola, "Prerequisites of formation and development of mainline electric locomotives engineering at the Luhansk diesel locomotives engineering plant (1957–2014)", *History of science and technology*, 10/1 (16) (2020), pp. 72-87, https://doi.org/10.32703/2415-7422-2020-10-1(16)-72-87

RUBAN, Mykola, FOMIN, Andrii, "Mastering and development of industrial production of rolling stock in Ukraine (1991-2022)", *History of science and technology*, 12/2 (2022), pp. 340-366, https://doi.org/10.32703/2415-7422-2022-12-2-340-366

SECCO, Michele; RAINER, Leslie; GRAVES, Kiernan; HEGINBOTHAM, Arlen; ARTIOLI, Gilberto; PIQUÉ, Francesca and ANGELINI, Ivana, "Ochre-based pigments in the tablinum of the House of the Bicentenary (Herculaneum, Italy) between decorative technology and natural disasters", *Minerals*, 11 (1) (2021), 67, https://doi.org/10.3390/min11010067

ŞERIFAKI, Kerem and İPEKOĞLU, Başak, "Execution technique and material characteristics of ceiling and wall paintings of an Ottoman period mansion in İzmir", *Gazi University Journal of Engineering and Architecture Faculty*, 36 (1) (2021), pp. 497-510, https://dergipark.org.tr/tr/pub/gazimmfd/article/690320

SUKAJ, Silvana; BEVILASQUA, Antonella; CIABURRO, Giuseppe; IANNACE, Gino and TREMATERRA, Amelia, "Ottoman mosques in Albania: Building acoustic exploration inside five case studies", *Buildings*, 11(10) (2021), 430, https://doi.org/10.3390/buildings11100430

TÜTÜNCÜ, Mehmet, *Corpus of Ottoman inscriptions from Albania and Montenegro*, Haarlem, Research Centre for Turkish and Arabic World Studies, 2017.

WANG, Yihui and WU, Xiaodong, "Current progress on murals: Distribution, conservation and utilization", *Heritage Science*, 11 (1) (2023), 94, https://doi.org/10.1186/s40494-023-00904-9

XU, Yichong, "Multidimensional Evaluation of Old Building Renovation Schemes", *Journal of Engineering Project and Production Management*, 16 (3) (2026), pp. 1-15, https://doi.org/10.32738/JEPPM-2025-364

YETIŞ, Ezgin; EROĞLU, Murat; ESKICI, Bekir; GÜR, Mahmut; DENIZ, Kiymet and KADIOĞLU, Yusuf, "Investigations of painting techniques: Edirne Süleyman Pasha Mosque wall paintings", *Studies in Conservation*, 68 (4) (2022), pp. 418-431, https://doi.org/10.1080/00393630.2022.2052642