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DBU-Project "Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague" (AZ 38228/01)

Final Report

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Summary

The project *Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague* (AZ 38228/01), funded by the Deutsche Bundesstiftung Umwelt (DBU) was carried out between January 2023 and March 2026 by TH Köln, the University of Pardubice (UPCE), and the State Academy of Fine Arts Stuttgart (ABK Stuttgart), in cooperation with Emmaus Abbey and the National Heritage Institute (NPÚ) of the Czech Republic. The project addressed one of the most significant surviving ensembles of medieval wall painting in Central Europe and aimed to develop recommendations for its long-term safeguarding, conservation, maintenance, and management. It was supported by cooperation with external experts and other institutions. Furthermore, it promoted students' active involvement, thereby contributing to applied training and quality education in wall painting conservation. The project combined archival research, detailed visual examination, environmental monitoring, risk assessment, advanced imaging techniques, non-invasive analytical investigations, and targeted micro-invasive material analyses. Particular emphasis was placed on developing a minimally invasive, interdisciplinary methodology to improve understanding of the wall paintings while reducing the need for sampling and physical intervention. This included the application of the *Rainbow* multispectral imaging system to the wall paintings, high-resolution photogrammetric imaging for documentation, climate monitoring, a systematic survey of liquid moisture, and the novel implementation of the ABC risk assessment method, adapted to the specific requirements of in situ wall paintings in a living heritage context. The project significantly improved understanding of the conservation history, material composition, painting technique, condition, and risk profile of the Emmaus Cycle. Archival research and scientific investigations demonstrated that the present appearance of the paintings is strongly influenced by conservation-restoration campaigns undertaken during the 1950s and 1960s. While these interventions successfully addressed many consequences of wartime damage, they also introduced materials and treatments that now present conservation challenges, including synthetic coatings, over-consolidation, and the removal of historical overpainting. The investigations further documented the original painting technique, identified conservation materials and deterioration products, assessed environmental and anthropogenic influences, and established a comprehensive evidence base for future decision-making. A major outcome of the project was the development of a strategic framework for future conservation planning. The recommendations prioritise organisational measures, preventive conservation, risk management, monitoring, maintenance, and phased testing before any direct interventions are considered. Opportunities for improving presentation and interpretation, including lighting improvements, digital reconstruction, and enhanced visitor information, were also identified. The conclusive recommendations provide a framework for preparing a future Conservation Plan and will be shared with Emmaus Abbey and the National Heritage Institute of the Czech Republic to support future conservation planning, decision-making, and management of the wall paintings. The results of the project have been disseminated through an international colloquium and are being made accessible through a project website, supported by Emmaus Abbey, and a richly illustrated final publication. Beyond its contribution to the future safeguarding of the Emmaus Cycle, the project demonstrated several transferable methodological approaches, including the use of remotely accessible environmental monitoring systems, systematic moisture-risk assessment, and the integration of value assessment and risk management through the ABC Method (CCI/ICCROM). The project therefore provides both a practical foundation for future conservation planning at Emmaus Abbey and a model for investigating, assessing, and planning the conservation of comparable wall painting ensembles and historic buildings.

Final Report

The present report summarises the implementation, results, and outcomes of the DBU-funded project *Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague* (AZ 38228/01). It provides an overview of the work undertaken between January 2023 and March 2026. Supplementary information is provided in the accompanying Appendix.

1 Introduction

The project was carried out between January 2023 and March 2026, including a three-month cost-neutral extension. Coordinated by TH Köln, it brought together a multidisciplinary team from the Cologne Institute of Conservation Sciences (TH Köln), the Faculty of Restoration of the University of Pardubice, and the State Academy of Fine Arts Stuttgart. The research was undertaken in close cooperation with the Benedictine Abbey of Emmaus in Prague and the National Heritage Institute of the Czech Republic (NPÚ). The project was further characterised by the active involvement of conservation students, external researchers, and multidisciplinary specialists, as well as by regular exchange with heritage authorities, academic institutions, abbey representatives, and other relevant stakeholders.

1.1 Project Background and Significance

The project focused on the medieval wall paintings in the cloister of Emmaus Abbey in Prague and aimed to provide an evidence-based foundation for their future conservation, stabilisation, management, and long-term safeguarding. Emmaus Abbey is designated as a National Cultural Monument of the Czech Republic. Together with the wall paintings of Karlštejn Castle and St Vitus Cathedral in Prague, the Emmaus Cycle is regarded as one of the most significant surviving ensembles of medieval wall painting in Central Europe. Dating from the reign of Emperor Charles IV in the fourteenth century, the cycle comprises scenes from the Old and New Testaments arranged within a complex iconographic programme and preserved today in twenty-six bay fields of the cloister. Its significance derives from its exceptional scale, artistic quality, historical importance, rarity, and high degree of preservation. As part of a functioning Benedictine monastery, the wall paintings form part of a living heritage site that remains in active religious use. The project therefore considered the cycle not as an isolated work of art, but within its architectural, historical, and contemporary functional context, including the abbey's daily routines, patterns of use, and controlled public accessibility.

1.2 Initial Situation

Despite the recognised significance of the Emmaus Cycle, the state of knowledge prior to the project remained fragmentary. Previous research had focused primarily on questions of authorship, iconography, and painting technique, often drawing on investigations and publications dating back several decades. By contrast, the twentieth-century conservation history of the wall paintings, their environmental context, and the long-term effects of conservation interventions and patterns of use had received comparatively little attention. The present condition of the wall paintings reflects a complex history of concealment, overpainting, wartime damage, restoration, and environmental influences. Severe losses of original material resulted from the destruction caused by an air raid during the final months of the Second World War. Their current appearance is particularly shaped by the conservation-restoration campaigns undertaken during the 1950s and 1960s led by Raimund Ondráček and Jiří Blažej, whose differing approaches to cleaning, conservation, and reintegration remain clearly visible today. While archival photographs, reports, and other documentation relating to these interventions existed, they were dispersed across multiple repositories and had been evaluated only in part. As a result, significant uncertainties remained regarding the extent of previous interventions, the materials

introduced during conservation campaigns, and their long-term impact on the wall paintings. Environmental influences represented a further area of uncertainty. The cloister had been exposed for long periods to atmospheric pollution from Prague's urban environment, and the condition of the paintings suggested the long-term effects of pollution, moisture, and changing environmental conditions, including possible sulphur-related alterations and gypsum formation. However, the causes and extent of these influences had not been systematically investigated. Before the project, no comprehensive interdisciplinary assessment of the entire wall painting cycle had been undertaken. Significant gaps therefore remained in the understanding of the paintings' conservation history, material composition, condition, deterioration processes, and environmental context and use-related risk. These knowledge gaps highlighted the need for a systematic investigation of the entire cycle and for the development of an evidence-based framework to support future conservation, maintenance, and safeguarding measures.

1.3 Project Objectives

The principal objective of the project was to develop recommendations for the preventive conservation, evaluation of necessary conservation interventions, and long-term safeguarding of the wall painting cycle in the cloister of Emmaus Abbey in Prague. Through the application of interdisciplinary investigative and documentation methods, the project also aimed to serve as a model for the assessment and safeguarding of comparable wall painting ensembles within the European heritage context. Given the exceptional significance of the cycle and the abbey's status as a National Cultural Monument of the Czech Republic, particular emphasis was placed on achieving a comprehensive understanding of the paintings' condition, material composition, conservation history, and environmental context. Special attention was given to the long-term effects of previous restoration campaigns, environmental influences, and other anthropogenic factors affecting the current condition and appearance of the cycle. A further objective was the development and application of a minimally invasive methodological approach combining complementary non-invasive examination, imaging and documentation techniques in order to maximise the information obtained while minimising physical sampling. The resulting documentation, assessments, and recommendations are intended to support future decision-making by the Emmaus Abbey, the National Heritage Institute of the Czech Republic and other responsible stakeholders. These recommendations will be reviewed by the National Heritage Institute and the City of Prague, which are the authorities responsible for issuing permits for the proposed treatment on the monument. The principal project tasks are summarised in the list below. A detailed overview is provided in the appendix.

1) Digitisation, cataloguing, and evaluation of archival and historical documentation.
2) Comprehensive condition assessment and documentation of the wall painting cycle.
3) Environmental and climate monitoring, including assessment of deterioration factors and pollution impacts.
4) Identification and differentiation of original paintings, overpaint, and later additions.
5) Analysis and evaluation of previous conservation and restoration interventions.
6) Application and integration of non-invasive analytical and imaging methods.
7) Assessment of anthropogenic influences, including restoration history, war damage, and environmental pollution.
8) Implementation of the ABC risk-assessment methodology and development of a risk-management framework.
9) Preparation of documentation and recommendations to support a future Conservation Plan.

10) Organisation of an international colloquium at Emmaus Abbey on the conservation, safeguarding, and presentation of the wall painting cycle.
11) Dissemination of project results through specialist publications and a final project publication.
12) Public accessibility of selected project documentation through digital presentation and online resources.

2 Work steps and Methods

This chapter outlines the work steps and methods applied during the project. The work was organised into a series of work packages (WPs), each coordinated by a lead partner and implemented in cooperation with the participating institutions (Table 1). The duration of the individual work packages varied according to their scope, and many activities were undertaken in parallel or in sequence, as illustrated in the project timeline (Table 2).

2.1 Overview of Work Packages and Project Timeline

Table 1: Overview of the work packages, including lead responsibility, participating partners and duration, DBU-funded project AZ 38228/01.

#	Work package (WP)	Lead	Partners	Duration [months]
1	Project Management	TH Köln	UPCE, ABK	36 +3
2	Research, Processing of the Archive Material, and Literature Research	UPCE	ABK Stuttgart	12
3	Visual Examination, Characterisation and Mapping of Individual Phenomena	UPCE	ABK Stuttgart, TH Köln	28
4	Investigation of Selected Areas Using Non-Invasive Imaging Techniques	ABK Stuttgart	UPCE, TH Köln	8
5	Investigation of Selected Areas Using Non-Invasive Analytical Methods	ABK Stuttgart	TH Köln, UPCE	16
6	Environmental Assessment, Climate Monitoring and Implementation of the ABC Risk Assessment Method	TH Köln	ABK Stuttgart, UPCE	36
7	Material Analysis with Invasive Analytical Methods	UPCE	ABK Stuttgart, TH Köln	22
8	Comprehensive Comparison and Evaluation of the Results of All Parts of the Survey and Recording	UPCE	ABK Stuttgart, TH Köln	13
9	Preparation and Organisation of the International Colloquium	UPCE	ABK Stuttgart, TH Köln	6

Table 2: Project timeline showing implementation and overlap of the work packages (WP), DBU-funded project AZ 38228/01.

WP	2023												2024												2025												2026		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
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note: month numbers refer to consecutive project months counted from the start of the project (Month 1 = January 2023).

2.2 Project Management (WP1)

Work Package 1 was led by TH Köln and continued throughout the entire project period. It comprised the overall coordination and administration of the project, including communication between project partners, organisation of regular online and in-person meetings, correspondence with the Deutsche Bundesstiftung Umwelt (DBU), preparation of interim and final reports, and financial management.

2.3 Research, Processing of the Archive Material, and Literature Research (WP2)

Work Package 2 was led by UPCE and focused on the identification, acquisition, digitisation, and evaluation of archival and literature sources relating to the wall painting cycle and its conservation history. Materials collected included historical photographs, conservation reports, surveys, and other relevant documentation. These sources were systematically catalogued and evaluated throughout the project and formed an important basis for understanding the conservation history, previous interventions, and current condition of the wall paintings. Selected archival materials were also prepared for inclusion in the project's planned digital dissemination activities.

2.4 Visual Examination, Characterisation and Mapping of Individual Phenomena (WP3)

Work Package 3 was led by UPCE in collaboration with ABK Stuttgart and focused on the systematic visual examination and documentation of the wall painting cycle. The paintings were inspected from mobile scaffolding, enabling detailed assessment of their condition, visible materials, surface phenomena and traces of earlier interventions. Photogrammetric surveys of all twenty-six bays and the four walls of the cloister were produced by the external specialist Ing. Jiří Vidman. These included high-resolution orthophotographs at different resolutions and shaded relief models, which provided the basis for documentation, mapping, and analysis. Additional photographic documentation was undertaken to record significant details and condition phenomena. Original materials, later additions, alterations, deterioration phenomena, and areas potentially requiring further monitoring or intervention were systematically recorded and catalogued. Graphic mapping was used to document selected aspects of the original painting technique, condition, and potential risks. Fieldwork and subsequent data processing were carried out during the first four monitoring campaigns and included participation by conservation students from UPCE during the 2023 and 2024 campaigns.

2.5 Investigation of Selected Areas Using Non-Invasive Imaging Techniques (WP4)

Work Package 4 was led by ABK Stuttgart in collaboration with UPCE and external specialists from the Czech Academy of Sciences. A range of non-invasive imaging techniques was applied to investigate the wall painting cycle and support the identification of materials, alterations, and conservation issues. These included infrared thermography carried out by Marek Eisler and Ing. Jaroslav Valach, Ph.D. from the Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences (CAS), ultraviolet-induced luminescence photography, performed by the UPCE team in cooperation with PhDr. Martin Mádl, Ph.D. from the Institute of Art History of the CAS. Subsequent spectral imaging in the visible, ultraviolet, and infrared ranges. Initial surveys of the entire cycle included infrared thermography and ultraviolet luminescence photography. Subsequent spectral imaging campaigns focused on selected areas of the paintings and were undertaken by UPCE and ABK Stuttgart, including an initial UPCE campaign on eight selected bays. A major component of the work was the application of the *Phase One* Rainbow Multispectral Imaging (MSI) Solution conducted by the ABK Stuttgart team in collaboration with Annette T. Keller. A joint student campaign involving students from both ABK Stuttgart and UPCE was integrated into this spectral imaging phase.

2.6 Investigation of Selected Areas Using Non-Invasive Analytical Methods (WP5)

Work Package 5 was led by ABK Stuttgart in collaboration with UPCE and external analytical specialists. A range of complementary non-invasive analytical methods was employed to investigate the material composition of selected areas of the wall paintings. These included portable X-ray fluorescence spectroscopy (pXRF), near-infrared spectroscopy (pNIRS), Raman spectroscopy (pRS), hyperspectral imaging (HSI), macro-X-ray fluorescence mapping (MA-XRF), and external reflectance Fourier-transform infrared spectroscopy (ER-FTIR). Initial pXRF measurements were carried out by UPCE while further

pNIRS, Raman, and pXRF measurements were undertaken by ABK Stuttgart in collaboration with Dr. Judit Zöldföldi from the Materials Testing Institute of the University of Stuttgart. A specialised analytical campaign was conducted with insiTUMlab at the Technical University of Munich (Dr Clarimma Sessa, head of the facility; Dr Eva Mariasole Angelin, Post-doc; Simon Mindermann, M.A., PhD candidate; and Monica Carraro, an Erasmus bachelor's student from Italy) in March 2025, including hyperspectral imaging, MA-XRF mapping, portable Raman spectroscopy, and ER-FTIR. Particular emphasis was placed on integrating analytical data with the results of visual examination, multispectral imaging, and archival research.

2.7 Environmental Assessment, Climate Monitoring and Implementation of the ABC Risk Assessment Method (WP6)

Work Package 6 was led by TH Köln and focused on establishing the environmental context of the wall paintings and assessing how the building, its use, and its surroundings influence their long-term preservation. The investigations considered the wall paintings within their architectural setting and continuing use as part of a living heritage site. The work package comprised environmental surveys and inspections throughout the abbey complex, including the cloister, church, adjacent rooms, upper floors, and attic spaces. Particular attention was given to environmental and anthropogenic risk factors, including solar exposure, surface temperatures, moisture-related phenomena, heating and ventilation conditions, and patterns of building use. A dedicated liquid moisture survey examined the occurrence and movement of water within the building envelope and its potential impact on the wall paintings. Microclimate monitoring was conducted between July 2023 and March 2026 using a network of 21 SIM-enabled data loggers that continuously recorded interior and exterior air temperature, relative humidity, and surface temperatures within the cloister and selected adjacent spaces. Historical and current environmental data, including sulphur dioxide monitoring records for Prague (1998–2024) retrieved from the Czech Hydrometeorological Institute, were evaluated alongside archival documentation to assess long-term environmental influences. Staff questionnaires and on-site observations also documented visitor activity, occupancy patterns, and building services, including heating and ventilation practices. Together, these investigations informed the interpretation of deterioration processes, the analysis of the monitoring data, and the assessment of environmental and use-related risks. To provide a structured framework for risk assessment, Dennis Mitschke (M.A.) implemented the ABC Method. This methodology identifies and prioritises risks to cultural heritage by combining a values-led assessment with the Ten Agents of Deterioration and a quantitative evaluation of the frequency and severity of potential damaging processes. Developed by the Canadian Conservation Institute (CCI) and ICCROM primarily for museum collections, the ABC Method seeks to balance long-term preservation with cultural significance, available resources, user needs, and sustainability (Michalski and Pedersoli 2016, *The ABC Method: A Risk Management Approach to the Preservation of Cultural Heritage*). Its adaptation and application within the context of a historic building represent an important innovation of the project.

2.8 Material Analysis with Invasive Analytical Methods (WP 7)

Work Package 7 was led by UPCE and focused on laboratory investigation of microsamples selected based on non-invasive examinations. Sampling locations were jointly identified by the project partners to address key questions regarding the original painting technique, material composition, conservation history, and deterioration processes. Sampling, sample preparation, and analytical investigations were carried out by the UPCE team. The analyses focused on the stratigraphy and composition of the paint layers and plasters, as well as on materials introduced during previous conservation interventions.

Particular attention was given to the identification of alteration products and other materials that may present conservation risks or influence the visual appearance and long-term stability of the wall paintings. The analytical programme included optical microscopy, scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM–EDX), Raman microspectroscopy (µRS), Fourier-transform infrared microspectroscopy (µFTIR), and gas chromatography–mass spectrometry (GC–MS). Selected µRS and µFTIR analyses were carried out in collaboration with Ing. Ivana Kopecká and Ing. Lucie Poláková from the National Technical Museum in Prague and Ing. Ladislav Lapčák and Doc. RNDr. Miroslava Trchová CSc., DSc. from the University of Chemistry and Technology Prague. GC–MS analyses were undertaken in collaboration with Dr. Václav Pitthard of the Kunsthistorisches Museum Wien. Sampling was undertaken in autumn 2024, with laboratory analyses continuing during the subsequent phase of the project and formed part of the project's educational activities involving students from both ABK Stuttgart and UPCE.

2.9 Comprehensive Comparison and Evaluation of the Results (WP 8)

Work Package 8 focused on integrating, comparing, and evaluating the findings from the individual investigations. Throughout the project, data and interim results were systematically archived on a shared cloud-based platform, facilitating collaboration and information exchange between project partners and external specialists. Preliminary findings were regularly presented, discussed, and reviewed during project meetings, enabling their progressive interpretation and synthesis. As part of this process, TH Köln, represented by Dennis Mitschke (M.A.), organised two ABC Risk Management workshops involving project partners and stakeholders. The adapted ABC Method provided a structured framework for assessing and prioritising the principal agents of deterioration affecting the in situ wall paintings. Combined with the cultural values assessment undertaken during the ABC process, the workshops enabled the evaluation of environmental and anthropogenic risks and helped establish a shared understanding of conservation priorities among the participants. TH Köln was responsible for synthesising the project findings, coordinating the interdisciplinary discussions, and preparing the recommendations and implementation framework, which were subsequently reviewed and refined by the project partners.

2.10 Preparation and Organisation of the International Colloquium (WP 9)

Work Package 9 focused on the preparation and organisation of an international three-day colloquium held at Emmaus Abbey in Prague in May 2025. The event was jointly organised by TH Köln, UPCE-FR, and ABK Stuttgart in close cooperation with the Abbey. Registration was managed online and, with support from the DBU, participation was free of charge. The organisational work included preparing the programme, coordinating speakers and participants, and producing conference materials, including a save-the-date flyer, programme, and book of abstracts. Students from UPCE-FR supported both the preparation and on-site organisation of the event. The programme combined presentations of project results with invited specialist contributions, site visits, and structured breakout group discussions. Project members presented interim findings and moderated discussions on issues relating to the conservation, safeguarding, presentation, and visual interpretation of the Emmaus Cycle. The outcomes of these discussions were incorporated into the final recommendations of the project.

3 Results

In accordance with the scope of this report, the following sections present a condensed summary of the principal project results. Detailed documentation, analytical data, technical information, and supporting material are provided in the appendices and are referenced in the relevant sections.

3.1 Conservation History and Restoration Campaigns

Archival research identified at least eight major phases of conservation and restoration work affecting the Emmaus Cycle during the twentieth century, ranging from interventions before the First World War to maintenance campaigns undertaken in the late 1980s. Approximately 900–1,000 historical photographs and associated archival documents were collected and evaluated, providing an important basis for reconstructing the conservation history of the paintings and assessing changes in their condition over time. Particular significance was attributed to the restoration campaigns undertaken by Raimund Ondráček and Jiří Blažej during the 1950s and 1960s. Although both sought to uncover and conserve the medieval paintings, their approaches differed considerably. Ondráček retained selected later overpaintings and relied extensively on synthetic consolidants and fixatives, whereas Blažej pursued a more purist approach, systematically removing overpaint and secondary layers in an effort to reveal the earliest Gothic paint layer. The two restorers also employed different consolidation materials, and their contrasting treatment philosophies are reflected in the final presentation of the paintings, particularly in the handling of large fills. From a contemporary conservation perspective, aspects of both approaches must be regarded critically, as some treatments involved introducing materials now considered unsuitable or removing historically significant surface layers. The investigations identified a wide range of materials associated with previous restoration campaigns, including synthetic polymers, overpaints, fills, and retouching materials. Analytical investigations confirmed the presence of polymers such as polymethyl methacrylate (PMMA) and polyvinyl acetate (PVAc), together with a variety of modern pigments and restoration materials. The identification and characterisation of these intervention materials have contributed significantly to reconstructing the conservation history of the wall paintings and provide an important basis for assessing their long-term stability, compatibility with historic materials, and implications for future conservation measures.

3.2 Painting Technique and Materials

A combined non-invasive and micro-invasive analytical approach, supported by detailed visual examination, enabled the stratigraphy, material composition, and painting technique of the wall painting cycle to be characterised. The investigations demonstrated that the paintings are works of exceptionally high craftsmanship and are consistent with contemporary medieval painting practices. The paintings were executed primarily in egg tempera or fatty egg tempera on a layered plaster support system. One of the most significant findings was the extensive use of white chalk grounds, locally combined with an ochre *imprimatura* composed of yellow earth pigments. The identified pigments closely match those commonly used in the fourteenth century and include lead white, natural chalk, earth pigments, minium, azurite, malachite, cinnabar/vermilion, and carbon black. The investigations also demonstrated that gilding played a substantially more important role in the original appearance of the cycle than previously recognised. Evidence was identified for both relief gilding and flat gilding, including gilded haloes, angels' wings, and a previously undocumented gilded stencil decoration comparable to that found at Karlštejn Castle. In addition, the study established a direct relationship between the wall paintings and the polychromy of the cloister's stonework, indicating a unified decorative programme. Analytical investigations also identified materials associated with later restoration campaigns. In particular, the presence of zinc- and barium-rich restoration materials in areas of loss and retouching provided further evidence for interventions carried out during the late nineteenth and twentieth centuries.

3.3 Current Condition and Deterioration Phenomena

The investigations provided detailed information on pigments, binders, plasters, degradation products, and restoration materials, contributing significantly to the interpretation of the wall paintings' material history and present condition. They indicate that the Emmaus Cycle is not currently exposed to any immediate or acute threat. Nevertheless, deterioration phenomena were identified that require continued monitoring and, in some cases, future conservation intervention. The observed deterioration results from a combination of factors, including the original painting technique, natural ageing processes, mechanical damage, environmental influences, and the legacy of previous conservation campaigns. In particular, some interventions undertaken during the extensive restoration campaigns of the 1950s and 1960s are now regarded as problematic. These include the intensive removal of overpaint and the extensive application of synthetic consolidants and surface coatings, which have contributed to localised gloss, yellowing, delamination, flaking, and blistering of the paint layers. Analytical investigations also identified material-related risks, including alteration of lead-based pigments resulting in the formation of dark plattnerite, contamination by soluble salts such as gypsum, chlorides, and oxalates, and the presence of aged synthetic polymer coatings. Condition mapping enabled a quantitative assessment of preservation and the extent of surviving original material. Excluding areas of replacement plaster in the lower wall zones, approximately 71% of the historic plaster and mural paintings survive. Preservation varies considerably across the cloister, ranging from approximately 79% in the west walk to 48% in the east walk. Percussion surveys further indicated that cavities affect approximately 15–30% of the surviving historic plaster, with some detached areas presenting an immediate conservation concern. A significant outcome of the investigation was the identification of technical and material differences in the painting of Bay 23(26), located above the former medieval portal to the Imperial Chapel. The evidence suggests that this painting may postdate the remainder of the cycle, raising important questions concerning the chronology, the sequence of execution, and the reconstruction of the original decorative programme.

3.4 Application of the *Phase One* Rainbow System on Wall Paintings

A major milestone of the project was the multispectral imaging campaign using the *Phase One* Rainbow Multispectral Imaging (MSI) Solution, undertaken by the ABK team in collaboration with expert Annette T. Keller. This represented one of the first applications of the fully automated system to wall paintings *in situ*. The system employed a *Phase One* iXH 150MP Camera System with specialised illumination to acquire high-resolution multiband (MB) and 16-channel narrowband (NB) image datasets. Image evaluation was carried out using Rainbow MSI and Capture One CH, enabling direct comparison of spectral responses and the identification of material variations across the painted surfaces. The imaging campaign supported the visualisation of original materials, historic repairs, retouching, and later conservation interventions through false-colour ultraviolet and infrared images. These datasets informed the selection of representative locations for subsequent non-invasive analyses and microsampling and were evaluated in conjunction with complementary analytical investigations.

The study also identified practical challenges associated with operating the system on scaffolding, particularly regarding stability, vibration, and the precise positioning of the camera and lighting. These experiences demonstrated the need for further optimisation of the mounting and movement system for future applications. Despite these limitations, the Rainbow MSI Solution proved highly effective as a bridge between conservation documentation, material characterisation, and scientific analysis. The integration of large-scale multispectral imaging with targeted analytical techniques enabled the identification of pigments, degradation products, and materials introduced during previous conservation campaigns, including synthetic organic restoration materials applied since the 1960s. The

results provided important new insights into the materials, condition, and conservation history of the wall paintings and formed the basis for subsequent laboratory investigations.

3.5 Anthropogenic and Environmental Influences

The assessment showed that the Emmaus Cycle is not currently exposed to any significant imminent environmental threat. Nevertheless, evidence of damage and deterioration resulting from historical events, past conservation interventions, environmental conditions, and present-day use was identified. Moisture- and salt-related deterioration was identified primarily as a localised risk rather than a uniform threat to the wall paintings. Soluble salts are present within the historic masonry and plaster, with efflorescence occurring only below or adjacent to the painted areas. One salt-affected area beneath the paintings was associated with a former pipe leak that has since been repaired. Regular inspections of roofs, drainage systems, rainwater pipes, and gutters are undertaken by the Abbey administration, and the water-management systems were found to be functioning effectively. These maintenance routines remain essential for preventing future water-related damage. The cloister microclimate is characterised by daily and seasonal fluctuations. Heating and ventilation are managed according to operational requirements rather than a fixed written schedule. Heating in adjacent rooms influences the environmental conditions within the cloister, with the south and west walks generally warmer, whereas the walk adjoining the church behaves differently. Recorded humidity levels did not indicate conditions conducive to mould growth, and only a few isolated condensation events occurred during January and February. Observations of the sun's movement showed that direct sunlight reaches the wall paintings only in the North walk and only under clear, sunny conditions. Under these conditions, sunlight falls directly onto Scenes 17(18) and 18(21) for approximately 45 minutes. Bay 17(18+19) also exhibits plaster bulging, which may be related to interactions between the plaster components and fluctuations in surface temperature. Exposure to direct solar radiation increases the surface temperature, resulting in a localised decrease in relative humidity due to the increased moisture-holding capacity of the air. The magnitude of this decrease depends on the extent of the temperature increase. Fluctuations in local relative humidity can place stress on the wall paintings, considering the hygroscopicity of added and altered materials like coatings or salts, which can explain the appearance of some phenomena in certain areas. Current use has left visible traces, particularly in the lower wall zones, including graffiti, fingerprints, and other forms of mechanical damage, some of which are associated with the use of scaffolding. A further example of mechanical damage to undecorated plaster was observed adjacent to the church entrance door, where the absence of a doorstop has allowed the door handle to repeatedly strike the plaster. Visitor data provided information on user groups, group sizes, seasonal distribution, movement patterns through the cloister, and increasing visitor numbers, confirming the importance of continued management of visitor access, maintenance, and use. The former coal-fired heating system, together with historic urban emissions in Prague, represents an important historical source of sulphur dioxide exposure. Evaluation of sulphur dioxide monitoring data between 1998 and 2024 indicates a substantial reduction in pollution levels, although slightly elevated concentrations continue to occur during the winter heating season. These findings contribute to understanding the historical formation of sulphate-related deterioration products identified within the wall paintings and their supporting materials.

3.6 Implementation of the ABC Method

The ABC risk assessment provided a structured framework for identifying, assessing, and prioritising natural and anthropogenic risks affecting the Emmaus Cycle. Within the project, it was adapted for application to the architectural and functional context of the cloister of Emmaus Abbey, which functions

both as a historic monument and as a site in continuous daily use. As an integral part of the assessment, the cultural values of the wall-painting cycle were evaluated, and a Statement of Significance was developed. Stakeholders participated in two workshops, enabling the assessment to incorporate conservation, heritage, and management perspectives. The assessment identified fire, water damage, structural deterioration, and human activity as the principal risk categories. These risks are particularly significant because they can affect not only individual stages of the wall-painting cycle but also the wider historic fabric and the Abbey's continued use. The final evaluation brought together the findings of all work packages and translated them into a coherent risk-based framework for future decision-making. The resulting recommendations for preventive conservation, maintenance, monitoring, emergency preparedness, and, where appropriate, future conservation interventions were further refined during a project meeting held in Cologne in January 2026, in which the project partners jointly reviewed the findings and agreed on the proposed implementation framework.

3.7 Research Data Management

ABK Stuttgart has confirmed the availability of the storage capacity and technical infrastructure required to host the project data. It is therefore planned that the digital documentation and research data generated during the project will be archived within a dedicated repository at ABK Stuttgart and made accessible for future research and conservation purposes. Implementation of the repository solution is scheduled for the end of 2027.

3.8 Dissemination

The project results were disseminated through an international three-day colloquium on *Murals Preservation - Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Monastery in Prague*, held at Emmaus Abbey from 22–24 May 2025, which attracted 105 participants from eleven countries representing a wide range of professional backgrounds, including academic researchers, conservators, heritage professionals, museum staff, and students. The event provided an important platform to present and discuss project findings and to exchange knowledge and experience with international specialists in wall-painting conservation and related fields. Further dissemination was achieved through specialist publications, media coverage, the project website, and a forthcoming English-language book publication entitled *The Emmaus Cycle: Wall Painting in Context and Close Up. Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus* Abbey *in Prague*. The volume will document both the colloquium and the principal outcomes of the project and is currently planned for publication in 2027 by the University of Pardubice. Upon completion of the final publication, the conclusive project results and recommendations will be communicated by the UPCE Team and discussed directly with the Emmaus Abbey Administration and the National Heritage Institute of the Czech Republic to support future decision-making, and long-term management of the wall paintings, and the preparation of a Conservation Plan.

4 Towards a Conservation Plan: Recommendations and Implementation Framework

The results presented in the previous chapter and the Appendix provide the evidence base for the following recommendations. This chapter does not constitute a comprehensive Conservation Plan for the Abbey; rather, it provides a strategic framework to support its future development. It translates the project findings into practical recommendations and a phased approach to decision-making, preventive conservation, risk management, monitoring, testing, and, where appropriate, implementation. The recommendations are intended as guidance rather than prescriptive requirements and may be

implemented progressively according to available resources, feasibility, and management priorities. They are designed to support Emmaus Abbey, the responsible heritage authorities, and other stakeholders in planning and prioritising future conservation measures. They are intended to be realistic, adaptable, and compatible with the Abbey's continuing religious function, available resources, and the needs of its residents, staff, and visitors, recognising that the wall-painting cycle forms part of a living heritage site.

4.1 Purpose and Scope

The recommendations presented in this chapter build upon the holistic approach developed during the project and provide a strategic framework for the long-term safeguarding, study, presentation, and management of the wall paintings in the cloister of Emmaus Abbey. They synthesise the principal project findings and define the organisational, preventive, investigative, indirect, and direct measures that may contribute to the development of a Conservation Plan. These include maintenance, monitoring, improved presentation, and, where necessary, future conservation interventions. The proposed approach begins with measures that reduce risk, improve preparedness, and strengthen the basis for informed decision-making. It progresses from indirect to direct conservation interventions only where further investigation, testing, documentation, monitoring, stakeholder agreement, and approval by the responsible heritage authority justify doing so. Rather than prescribing a single treatment campaign, the framework provides a flexible basis for prioritising phased implementation according to need, available resources, and emerging knowledge.

4.2 Framework for Action

The recommendations are organised into four interrelated categories of action: **Organisational Measures**, **Preventive Measures**, **Visualisation Measures**, and **Direct Treatment Interventions**. Together, these form an integrated framework that progresses from strengthening management, planning, and risk preparedness through preventive and visualisation measures to direct treatment interventions, where justified by the condition of the wall paintings and the long-term conservation objectives.

Table 3: Recommended framework for action supported by maintenance, long-term monitoring and documentation, DBU-funded project AZ 38228/01.

#	Action Category	Purpose	Indicative examples
1	**Organisational Measures**	Establish the framework for planning, decision-making and implementation	Advisory group, stakeholder involvement, interest groups, funding, research data management
2	**Preventive Measures**	Reduce risks and improve preparedness without direct treatment of the wall paintings	Emergency contacts and procedures, emergency plan, H&S training, fire safety, reduce water ingress, safer access, scaffolding and use-related guidance, reduce UV insolation
3	**Visualisation Measures**	Improve presentation, interpretation and understanding without physical treatment of the painted surfaces	Lighting, digital reconstruction, digital retouching, projection, visitor information, website, QR codes
4	**Direct Treatment Interventions**, Including Treatment Testing with Evaluation and Potential Larger-Scale Interventions	Define possible physical measures requiring further investigation, testing, documentation and approval	Emergency stabilisation, cleaning, consolidation, grouting/securing, fills, coating reduction, retouching/reintegration
+	Continuous activities	Maintenance, monitoring and documentation	Evaluation, regular inspections, photographic documentation, condition surveys, environmental monitoring, data management

Organisational Measures establish the conditions necessary for planning, decision-making, funding, data management, and implementation. **Preventive Measures** focus on risk reduction, preparedness,

and the mitigation of avoidable deterioration. Visualisation Measures improve the presentation, interpretation, accessibility, and public understanding without physically treating the wall paintings. Direct Treatment Interventions, including treatment testing, evaluation, and any subsequent larger-scale interventions, comprise physical conservation measures that require further investigation, testing, documentation, evaluation, and approval before wider implementation. Maintenance, monitoring, and documentation are continuous activities that support all four categories of action. They provide the information necessary for preventive conservation, informed decision-making, and the evaluation of implemented measures. Table 3 illustrates the relationship between the four categories of action and the continuous supporting activities. It should be understood as a flexible framework for future planning, prioritisation, and implementation rather than as a fixed programme of works.

4.3 Category 1: Organisational Measures

The following recommendations aim to strengthen the organisational basis for future conservation planning, decision-making, implementation, and long-term management of the wall paintings. They focus on responsibilities, stakeholder involvement, communication, funding, documentation, and research data management.

Recommendation 1.1 – Stakeholder Involvement

Relevant stakeholders should be involved or consulted at appropriate stages according to their role and the nature of the measures under consideration. These may include the Abbey administration, the monastic community, heritage authorities, conservators, art historians, researchers, visitors, educational users, funding bodies, and institutions responsible for the long-term preservation of research data and archival documentation.

Recommendation 1.2 – Establishment of an Advisory Board

The long-term management of the wall paintings would benefit from establishing an advisory board comprising national and international specialists, including heritage officials, wall painting conservators, conservation scientists, and art historians. In consultation with relevant stakeholders, the board could provide strategic advice, facilitate knowledge exchange, support future research initiatives, and assist in identifying funding opportunities. Such a structure would support informed decision-making and contribute to the sustainable conservation and future development of the site.

Recommendation 1.3 – Funding Strategy

As several recommended measures will require additional resources, suitable funding opportunities should be explored at an early stage. This applies particularly to lighting trials, in situ conservation testing, extended monitoring, and potential pilot interventions or follow-up projects. Possible sources may include public funding programmes, research collaborations, conservation partnerships, and, where appropriate, cooperation with manufacturers or technical specialists.

Recommendation 1.4 – Documentation and Data Management

Long-term preservation of project documentation and research data is recommended through appropriate archiving procedures, including maintaining copies of key project materials at the Abbey and encouraging collaboration with universities and conservation institutions. For future conservation testing, documentation, and monitoring, protocols should be established from the outset to ensure the systematic recording, evaluation, and assessment of changes over time.

Recommendation 1.5 – Ongoing Communication

Ongoing communication between Emmaus Abbey, the responsible heritage authorities, conservation specialists, researchers, and other relevant stakeholders should be maintained throughout future planning and implementation processes. Clear communication channels would support the

coordination of responsibilities, the timely exchange of monitoring and maintenance information, and the preparation of decisions concerning future conservation, presentation, and management measures.

4.4 Category 2: Preventive Measures

The following recommendations aim to reduce risks to the wall paintings, the historic building, and associated collections without directly treating the painted surfaces. They focus on preparedness, emergency response, safer access, training, maintenance routines, and the management of environmental and use-related risks.

Recommendation 2.1 – Fire Preparedness (Highest Priority)

Given the potential consequences for human life, the monastic community, the historic building, and the wall paintings, fire represents the most significant identified risk. Preparedness should be strengthened through improved detection systems, emergency planning, staff training, regular inspections, and coordination with the local fire brigade. Particular attention should be given to vulnerable areas, emergency access procedures, sensitive archival materials, and flammable substances.

Recommendation 2.2 – Water Damage Preparedness

Preparedness for water-related emergencies should be strengthened through clear response procedures, routine inspection of vulnerable areas, and appropriate staff training. Emergency documentation and regular monitoring should support the early identification and management of water ingress, thereby reducing the risk of damage to the building, its collections, and the wall paintings.

Recommendation 2.3 – Structural Monitoring and Maintenance

Although structural deterioration does not currently pose an immediate threat to the wall paintings, it may compromise visitor safety and the building's long-term stability. Preventive measures should include regular monitoring of cracks and other vulnerable architectural elements, targeted structural assessments when movement is observed, and periodic reviews by qualified structural engineers. Temporary protective measures may be introduced where necessary to ensure the safe use of the cloister.

Recommendation 2.4 – Organisational Preparedness and Risk Management

Preventive conservation should be supported by clear organisational structures and procedures. Recommended measures include preparing an emergency plan, establishing emergency response protocols, identifying responsibilities and key contacts, and periodically reviewing risks using structured assessment methodologies such as the ABC Method. Conservation requirements should also be incorporated into contracts for external contractors and service providers.

Recommendation 2.5 – Training and Awareness

Regular training and awareness-raising activities should be provided for staff, residents, tenants and other site users. Guidance should address both health and safety issues and the specific vulnerabilities of the wall paintings and historic fabric. Procedures should also be communicated to external contractors, researchers, and film crews whose activities may affect the site. Visitor management measures should seek to minimise accidental damage while promoting understanding of the Abbey's cultural heritage.

Recommendation 2.6 – Equipment and Infrastructure

Appropriate equipment and infrastructure should be maintained through regular inspection, maintenance, and replacement where necessary. This includes access equipment, emergency response equipment, and simple preventive measures such as door stoppers to reduce vibration and minimise the risk of accidental damage to the historic fabric and wall paintings.

Recommendation 2.7 – Maintenance and Long-Term Monitoring Programme

A structured maintenance and long-term monitoring programme should be established to support the preservation of the wall paintings, the historic building, and associated collections. Regular inspections should focus on areas affected by condensation, unstable plaster, cracking, or other forms of deterioration. Monitoring should be supported by systematic photographic documentation and, where necessary, close visual examination from scaffolding. Comprehensive condition surveys undertaken by qualified conservators are recommended at approximately five-year intervals and should be compared with the baseline documentation and findings of the present project. Monitoring of cracks, vibration, environmental conditions, and other relevant parameters should continue in order to detect change at an early stage and inform future conservation decisions. The installation of UV-protective glazing in the North Walk is recommended to reduce the risk of light-induced deterioration of the wall paintings.

4.5 Category 3: Visualisation Measures

The following recommendations aim to improve the presentation, interpretation, and accessibility of the wall paintings through non-invasive measures. They focus on lighting, visitor information and access, digital technologies that can enhance understanding and appreciation of the Emmaus Cycle.

Recommendation 3.1 – Improvements to the Lighting System

The current lighting system could be improved to enhance the visibility and appreciation of the wall paintings for both the monastic community and visitors. Alternative lighting solutions should first be tested in a pilot bay, including the evaluation of colour temperature, tuneable LED lighting systems, and metameric effects. Particular attention should be given to achieving diffuse, evenly distributed illumination that improves legibility and directs attention to the paintings. Following successful testing and evaluation, a permanent lighting system could be installed and the existing temporary lighting stands removed.

Recommendation 3.2 – Information Access and Visitor Interpretation

Visitor engagement could be enhanced through improved interpretation and information resources, including expanded written content, QR-code-based information, audio guides, and printed materials. Particular attention should be given to accessibility and multilingual provision. In the longer term, these measures may allow the replacement of the existing display boards with less visually intrusive interpretative solutions.

Recommendation 3.3 – Website-Based Access and Digital Resources

The project website should be maintained and further developed as a platform for public access to project results, photogrammetric documentation, the 3D model of the cloister, and interpretative content relating to the Emmaus Cycle. The website can support both public engagement and professional access to selected project data and documentation.

Recommendation 3.4 – Digital Reconstruction and Interpretation

Digital reconstruction offers a non-invasive means of visualising heavily damaged or lost scenes using historical photographs and surviving evidence. Initially, such reconstructions could be made accessible online, with future possibilities including on-site digital displays or projection systems. In addition to improving understanding of the iconography and original appearance of the cycle, digital reconstructions can communicate the history of damage, restoration, and conservation while remaining adaptable to future technologies.

Recommendation 3.5 – Digital Retouching and Visualisation

Digital retouching may serve as a valuable tool in the development of future conservation strategies. By enabling different reintegration and presentation approaches to be tested and compared digitally

before any physical intervention, it provides a reversible and transparent means of evaluating aesthetic options, facilitating stakeholder discussion, and supporting informed conservation decision-making.

4.6 Category 4: Direct Treatment Interventions

The following recommendations identify potential direct treatment measures that may be considered only when necessary, proportionate, and supported by sufficient evidence. They focus on treatment testing, including mechanical cleaning, stabilisation, coating reduction, the assessment of historic repairs, and possible improvements to visual integration. As treatment testing itself constitutes a direct intervention, all such measures should be carefully planned, documented, monitored, evaluated, discussed with relevant stakeholders, and approved before any wider implementation.

Recommendation 4.1 – Selection of Pilot Bays and Test Areas

Future test interventions and possible wider measures should be undertaken in carefully selected pilot bays or representative test areas that are well documented, accessible with minimal disruption to monastic life, and representative of different conservation conditions and previous treatments. Bay 24/31 in the East Walk has been identified as a potential candidate, although the final selection should be reviewed as planning develops. Test areas should be selected to address clearly defined conservation questions relating to surface deposits, unstable paint and plaster layers, historic coatings, historic repairs, and the visual presentation and integration of previous interventions.

Recommendation 4.2 – Mechanical Surface Cleaning

Following appropriate evaluation and testing, selected areas may be suitable for careful mechanical cleaning to remove superficial dust, debris, cobwebs, and biological deposits. The presence of soluble salts within the historic masonry and plaster should be considered when considering any aqueous cleaning methods. Mechanical cleaning has the potential to improve the legibility of the wall paintings and facilitate future documentation, monitoring, and conservation activities.

Recommendation 4.3 – Stabilisation of Vulnerable Paint and Plaster Layers

Future conservation interventions should prioritise the stabilisation of vulnerable paint and plaster layers, particularly in areas at risk of ongoing deterioration or material loss. Measures may include securing detached plaster, grouting voids, consolidating unstable paint layers, and treating areas affected by structural movement or coating-related tensions. Suitable grouting, consolidation, and securing materials should first be tested in representative areas. The prioritisation of interventions should be informed by condition assessments, material investigations, and ongoing monitoring.

Recommendation 4.4. – Assessment and Stabilisation of Historic Repairs

Historic repairs and fills should be systematically assessed and classified according to their condition, material characteristics, significance, and visual impact. This assessment should inform the prioritisation of future interventions and provide a framework for decision-making. Repairs showing signs of instability should be stabilised as part of future conservation campaigns, with particular attention given to vulnerable fills and their interfaces with adjacent original material. Where necessary, consolidation and grouting measures should be coordinated to improve the overall structural stability of the wall paintings.

Recommendation 4.5 – Reduction of Historic Surface Coatings

The controlled reduction of historic surface coatings may be considered where it would reduce yellowing and gloss, improve legibility, and, where possible, enhance the capillary and vapour-transfer properties of the painted surfaces. Particular attention should be given to changes in gloss, colour saturation, capillarity, vapour permeability, and the stability of underlying paint layers. Evaluation should be supported by photographic documentation, microscopic examination, UV imaging, and other

appropriate analytical methods. Given the varying condition of the wall paintings and the presence of multiple historic coating campaigns, any treatment strategy should be developed on a bay-by-bay basis.

Recommendation 4.6 – Improvement of the Visual Integration of Historic Repairs and Loss

Following the stabilisation of the wall paintings and historic repairs, consideration may be given to improving the visual integration of selected fills and losses. Current issues include inconsistencies in surface level, texture, and colour, as well as areas where historic repairs overlap original painted surfaces. Future investigations should assess whether problematic repairs can be modified, reduced, or retained while respecting the historical significance of previous conservation campaigns. Digital visualisation and digital retouching should be used where appropriate to compare alternative treatment scenarios and support stakeholder discussion before any physical intervention is undertaken.

4.7 Risk-Based Prioritisation and Phased Implementation

Future conservation planning should be guided by risk, urgency, feasibility, available resources, stakeholder agreement, and the principles of minimum intervention, compatibility, reversibility, where possible, and long-term sustainability. The recommendations presented in this framework should therefore be regarded as a flexible decision-making tool rather than a fixed programme of works. Priority should generally be given to measures that reduce risk, improve preparedness, strengthen monitoring and documentation, and support informed decision-making. Organisational and preventive measures should normally precede indirect and direct interventions, while maintenance and monitoring should continue throughout the process. Where test interventions, pilot measures, or alternative conservation scenarios are proposed, their results and implications should be reviewed with relevant stakeholders before decisions on wider implementation are made. Such reviews should consider the extent of the proposed measures and weigh their potential benefits against their costs, practical implications, conservation risks, reversibility, long-term maintenance requirements, and possible effects on the appearance and significance of the wall paintings. The phased approach proposed here is intended to support sustainable and evidence-based conservation planning while maintaining sufficient flexibility to respond to new information, changing conditions, and future priorities.

4.8 Future Conservation Scenarios and Phased Implementation Strategy

Phased Implementation: As an indicative structure, implementation may be organised in three phases. These phases are not strictly sequential but describe a general progression from organisational and preventive foundations towards testing, evaluation and possible wider implementation. Maintenance, monitoring and documentation should continue throughout all phases and do not constitute a separate category of action.

→ **Phase 1 Organisational and Preventive Basis:** Focuses on measures that reduce risk, improve preparedness and strengthen the basis for future decisions. This includes organisational measures, emergency preparedness, maintenance routines, monitoring and documentation. Selected indirect measures may also be initiated when they improve access, presentation, or future decision-making.

→ **Phase 2 Testing and Pilot Phase:** Involves targeted investigations, conservation testing, representative test areas and pilot interventions. The results should be documented, monitored, and evaluated to determine whether the measures are suitable, necessary, and proportionate before wider application is considered.

→ **Phase 3 Wider Implementation of Treatments:** Comprises the implementation of larger conservation campaigns and broader presentation improvements only where these are justified by the results of previous phases, available resources and stakeholder agreement. Monitoring,

documentation and maintenance should continue after implementation in order to assess the long-term performance and consequences of the measures.

Indicative Conservation Scenarios: The following scenarios are intended for discussion. They describe different degrees of possible action and do not represent fixed treatment options. The phases described above concern the sequence of implementation, whereas the scenarios below concern the extent and character of possible intervention.

→ **Scenario 1: Preventive Measures Only:** This scenario focuses on preventive conservation through risk management, regular monitoring, documentation, and the development of digital interpretation tools. No direct intervention on the wall paintings would be undertaken.

→ **Scenario 2: Stabilisation Programme:** This scenario prioritises the physical conservation of the wall paintings through emergency stabilisation measures, grouting, consolidation, and the controlled reduction of surface coatings where appropriate.

→ **Scenario 3: Stabilisation and Selected Presentation Improvements:** Building upon the stabilisation programme, this scenario includes selected measures to improve the visual integration of historic repairs and losses, enhancing the overall presentation and legibility of the wall paintings. It may include limited reintegration or carefully evaluated coating reduction, where justified by testing and agreement.

→ **Scenario 4: Comprehensive Conservation and Presentation Programme:** This scenario represents the most extensive approach, combining preventive conservation, remedial interventions, presentation improvements, and interpretative measures within a coordinated long-term conservation strategy.

5 Comparison of Achieved and Planned Results

Table 4 provides a summary comparison between the twelve project objectives defined in the original project proposal and the outcomes achieved during the project.

Table 4: Overview with comparison of achieved and planned results, DBU-funded project AZ 38228/01.

No.	Objective	Status	Actual result	Additional explanation/follow-up
1	**Digitisation and cataloguing of archival material**	Largely completed	Archival material was collected, evaluated and structured for project documentation, conservation history and future data archiving.	Records relating to approximately 200 samples collected by Jiří Blažej and his personal work diaries remain to be processed
2	**Documentation and assessment of the current condition**	Completed	All 26 bays were examined in situ, with photographic cataloguing of individual phenomena, technical mapping of the original painting technique throughout, detailed condition mapping for 8 bays and summary mapping for the remaining 18 bays.	Future work could extend to the cloister vaults and adjacent spaces, such as the fragment of medieval painting in the church.
3	**Climate and environmental monitoring**	Completed	Environmental conditions, moisture-related risks, historic pollution data, heating history and current use were assessed through on-site inspections, liquid moisture surveys and microclimate monitoring.	Minor monitoring gaps occurred due to technical issues and were compensated by additional measurements and cross-checking.
4	**Differentiation of original painting and later overpainting**	Completed	Original material, later overpainting, retained layers and restoration-related surface areas were differentiated on an area-specific basis.	Interpretation remains cautious in areas with complex stratigraphy.
5	**Differentiation and evaluation of previous restoration measures**	Completed	Previous interventions and conservation materials were identified and evaluated in relation to condition and future conservation requirements.	Results informed the conservation history and future treatment recommendations.
6	**Combined non-invasive examination**	Completed with adaptations	Imaging and analytical investigations successfully characterised original materials, degradation phenomena, and conservation materials	On-site conditions required methodological adaptations, especially for imaging with Rainbow System on scaffolding.

No.	Objective	Status	Actual result	Additional explanation/follow-up
7	**Assessment of anthropogenic influences**	Completed	Historic alterations, war damage, pollution, previous restoration campaigns and current use were assessed as factors affecting the wall paintings.	Results were integrated into the condition interpretation and risk assessment.
8	**ABC-based value and risk assessment**	Completed	Values and risks were assessed using the ABC Method. Two workshops were conducted, and a Statement of Significance was developed.	The assessment provided the basis for risk management and prioritisation of recommendations.
9	**Documentation supporting a future Conservation Plan**	Completed	Recommendations were developed to support future decision-making and conservation planning, including categories of action, phased implementation, and conservation scenarios.	The framework can support future decision-making; implementation will require future coordination, approvals, and funding.
10	**International colloquium**	Completed	The international colloquium was held at Emmaus Abbey from 22–24 May 2025 and presented the project results to a professional audience.	The colloquium supported professional exchange, student involvement and preparation of the final publication.
11	**Dissemination through specialist articles and a final publication**	In progress	Project results were disseminated through specialist presentations and publications and will be further disseminated through an English-language book currently in preparation.	The publication is planned for 2027 and continues as post-project dissemination.
12	**Public access through the Emmaus Abbey website**	In progress	Selected photographic and graphic documentation was prepared for online presentation.	The website and spatial presentation of the cloister are being finalised.

6 Discussion and Evaluation

6.1 Evaluation of Project Outcomes

The comparison of planned and achieved results (Table 4) demonstrates that the principal objectives of the project were successfully fulfilled. All core investigative, documentation, environmental assessment, analytical, and risk assessment activities were completed, providing a comprehensive understanding of the wall painting cycle, its conservation history, current condition, material composition, and future conservation requirements. Only a limited number of tasks remain incomplete. These relate primarily to the final processing of selected archival materials, the publication of project results, and the completion of the website and digital dissemination platform. These activities do not affect the achievement of the project's principal objectives and will be completed during the post-project dissemination phase. The digital documentation and research data generated during the project will be archived and results and recommendations directly communicated and discussed with the Emmaus Abbey Administration and the National Heritage Institute of the Czech Republic. Overall, the project has established a robust foundation for the future safeguarding, management, and conservation of the Emmaus Cycle. Through the integration of archival research, condition assessment, scientific investigation, environmental monitoring, and risk assessment, the project has provided a comprehensive evidence base for future decision-making and conservation planning.

6.2 Deviations, Limitations and Follow-up Tasks

The deviations from the original work plan were limited and did not affect the achievement of the principal project objectives. They relate primarily to follow-up tasks extending beyond the formal project period, including the processing of selected archival materials, implementation of the long-term data repository, completion of the project website, and publication of the final volume. A project extension was requested principally to support the publication process, including the coordination of external authors, editorial review, and the commissioning and scheduling of the graphic designer and printing company. The extension therefore related to dissemination and production rather than to the completion of the core investigations, assessment, and recommendations. Some methodological limitations were encountered during the project. Environmental monitoring was affected by occasional

data gaps caused by technical issues, while the use of advanced imaging systems on scaffolding required adaptation to the spatial and practical conditions of the cloister. In addition, the interpretation of some areas remains cautious owing to the complex stratigraphy of added and altered materials. During the project, the DBU approved a revision to the English project title from *Preventive Conservation, Securing and Preservation of the Cycle of Wall Paintings in the Emmaus Monastery in Prague* to *Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague*. The revised title more accurately reflects the scope of the project, encompassing not only preventive conservation and risk reduction but also recommendations for the long-term safeguarding, management, and, where appropriate, future conservation of the wall-painting cycle.

6.3 Organisation and Implementation of Cooperation

The project was implemented through close cooperation between TH Köln, the University of Pardubice (UPCE), and the State Academy of Fine Arts Stuttgart (ABK Stuttgart), each contributing complementary expertise in conservation, heritage science, imaging, environmental assessment, and risk management. TH Köln was responsible for overall project coordination, environmental investigations, risk assessment, communication with the DBU, and the development of recommendations. UPCE led the archival research, condition assessment, visual examination, sampling, and laboratory investigations, while ABK Stuttgart was responsible for advanced imaging and non-invasive analytical investigations. The project was undertaken in close collaboration with Emmaus Abbey, the National Heritage Institute of the Czech Republic, external specialists, and other stakeholders. Regular online and in-person meetings, shared digital data platforms, joint field campaigns, workshops, and the International Colloquium ensured the continuous exchange of information and facilitated the integration of results across disciplines. The participation of students, early-career researchers, and external experts further strengthened interdisciplinary collaboration, knowledge transfer, and capacity building.

6.4 Evaluation of Environmental and Methodological Outcomes

Beyond the specific findings relating to the Emmaus Cycle, the project generated several methodological outcomes of broader relevance to the conservation of wall paintings and historic buildings. These include the development and testing of a systematic Liquid Moisture Survey methodology for identifying and assessing moisture-related risks at building and site level; the adaptation and implementation of the ABC risk assessment method for in situ wall paintings within a living heritage context; and the installation of a network of remotely accessible environmental loggers that enabled continuous monitoring of environmental conditions and the automated transmission of alerts when predefined threshold values were exceeded. Together, these approaches demonstrate practical and scalable methods for integrating environmental assessment, risk management, monitoring, and preventive conservation planning. As such, they contribute to the project's model character and may serve as useful references for comparable conservation projects in the future. The methodological approaches adopted during the project also contributed to resource-conscious conservation planning. The predominantly non-invasive and minimally invasive investigation strategy reduced the need for physical intervention and sampling while still providing a comprehensive understanding of the wall paintings and their condition. By linking environmental monitoring data with condition phenomena, patterns of use, and the architectural context, the project strengthened the basis for preventive conservation and value- and risk-informed decision-making. This approach can help avoid premature, repeated, or insufficiently justified interventions and supports more efficient use of conservation resources. The project also generated valuable experience in the application of advanced imaging systems, particularly the *Phase One* Rainbow System, demonstrating both its analytical potential and the practical challenges associated

with large-scale in situ imaging, including issues of scaffolding stability, lighting control, dust, and data management.

6.5 Economic Relevance, Model Character and Transferability

The economic relevance of the project lies primarily in improving the basis for future decision-making rather than generating direct cost savings. By providing a comprehensive understanding of condition, risks, and conservation priorities, the project supports the more efficient allocation of financial, technical, and personnel resources and helps distinguish urgent stabilisation needs from measures that may be deferred or implemented in phases. The recommendations and implementation framework also provide a clearer basis for future funding applications and investment planning. The project further demonstrates a transferable methodology for investigating, assessing, and planning the conservation of complex wall painting ensembles. The integration of archival research, environmental assessment, non-invasive investigation, risk management, stakeholder participation, and preventive conservation planning provides a model that may be adapted to comparable heritage sites. In this respect, the project's significance extends beyond Emmaus Abbey and contributes to the wider development of conservation practice.

7 Public Relations

Given the project's role as a model for the investigation, assessment, risk management, and conservation planning of complex wall painting ensembles, considerable importance was attached to public outreach and professional dissemination throughout the project. The main dissemination activities, including the international colloquium and the final publication, are summarised in Chapter 3.8. Additional public relations and professional dissemination activities included regional and national media coverage, press releases, institutional websites, social media posts by the project partners and Emmaus Abbey, specialist meetings, workshops, and conference contributions. A detailed list of media reports, online posts, social media activities, lectures, conference contributions, and publication outputs is provided in the Appendix. The professional community, including representatives of the National Heritage Institute, the Czech Academy of Sciences, universities, conservation professionals, and representatives of Emmaus Abbey, was actively involved through project meetings, workshops, and consultations, particularly in relation to the application of the ABC Method and the development of recommendations. The project was also presented to the professional community through conference and lecture contributions, including a presentation at the Czech Academy of Sciences and a poster presentation at the TECHNART 2025 in Perugia, Italy. Further dissemination is being achieved through planned peer reviewed publications, a dedicated project website, financed by the Emmaus Abbey, and a forthcoming edited volume planned for publication in 2027. The website includes general information about the project, a virtual 3D tour of the cloister, photogrammetric documentation of the wall paintings, and interpretative content for a wider audience. Selected project data will also be made accessible to specialists, while the project documentation and research data will be archived to support future research and conservation activities. The project directly benefits Emmaus Abbey, the monastic community, the National Heritage Institute, the responsible heritage authorities, future conservation teams, students and early-career professionals involved in the project. Their participation in fieldwork, documentation, imaging, analytical investigations, risk assessment discussions, and the international colloquium contributed to quality education, capacity building, and professional knowledge transfer. Beyond its contribution to safeguarding the Emmaus Cycle, the project demonstrates an interdisciplinary, predominantly non-invasive approach to investigating, assessing, managing risks, and planning the conservation of complex wall-painting ensembles. As such, it provides a model that may

be relevant to heritage professionals, public authorities, monument owners, and researchers working on comparable cultural heritage sites.

8 Conclusion

The principal objective of the project was to develop recommendations for the long-term safeguarding, conservation, maintenance, and management of the Emmaus Cycle. To achieve this, the project combined archival research, visual examination, advanced imaging techniques, non-invasive and micro-invasive material investigations, environmental monitoring, and risk assessment based on the ABC Method. Although the Emmaus Abbey and its wall paintings have been the subject of numerous studies, this project represents the first comprehensive assessment of the cycle's condition, conservation history, risks, and future conservation needs. The investigations demonstrated that the present condition and appearance of the wall paintings are strongly influenced by the major conservation-restoration campaigns of the 1950s and 1960s. While these interventions successfully addressed many of the problems arising from wartime damage, they also introduced materials and treatments that now present conservation challenges. These include excessive consolidation, glossy surface coatings, localised flaking and paint loss, and the removal of historically significant overpaint and secondary layers. The project also highlighted inconsistencies in the visual presentation of the cycle resulting from differing conservation approaches adopted during this period. In addition to improving understanding of the paintings' conservation history, the project identified opportunities to enhance their future presentation and interpretation. These include improvements to the lighting system, the use of digital visualisation and reconstruction, and the possible treatment of selected historic repairs and surface coatings. Any such measures should be preceded by further investigation, testing, and evaluation. Environmental investigations demonstrated that the wall paintings are currently exposed to relatively limited climatic risks. At the same time, the application of the ABC Method provided a structured basis for assessing environmental, structural, and anthropogenic risks and for developing future monitoring, maintenance, and risk-management strategies. The project has demonstrated the value of an interdisciplinary and preventive approach to the care of complex wall painting ensembles. By integrating historical research, scientific investigation, environmental assessment, stakeholder participation, and risk management, it has established a robust basis for future decision-making concerning the Emmaus Cycle and its long-term safeguarding. As the project focused on developing recommendations rather than implementing them, a number of tasks remain for subsequent phases of work. These include testing and refining lighting solutions, developing digital reconstruction and interpretation tools, and evaluating proposed conservation treatments through pilot studies. Nevertheless, the project provides a sound and evidence-based foundation for the future conservation, management, maintenance, and presentation of the Emmaus Cycle. Moreover, its integrated methodology offers a transferable model for the investigation, assessment, risk management, and preparation of conservation recommendations for comparable wall painting ensembles and heritage sites elsewhere.

9 Lists

9.1 List of Tables

9.2 List of Abbreviations

ABK Stuttgart	Staatliche Akademie der Bildenden Künste Stuttgart
AT	Ambient temperature
AVU	Academy of Fine Arts in Prague
AZ	Aktenzeichen
BW	Black and White
CAS	Czech Academy of Sciences
CICS	Cologne Institute of Conservation Sciences
ČTK	Czech Press Office
DBU	Deutsche Bundesstiftung Umwelt
DP	Dew point
EDX	Energy-Dispersive X-Ray
e.g.	For example
ER-FTIR	External-Reflectance Fourier-Transform infrared spectroscopy
HSI	Hyperspectral imaging
i.e.	For instance
GC-MS	gas chromatography with mass spectroscopy
IR	Infrared
IRR	Infrared reflectance
IRRFC	Infrared reflectance false colour
MA-XRF	Macro-X-Ray Fluorescence
MB	Multiband
MPA	Materials Testing Institute (at the University of Stuttgart)
MSI	Multispectral imaging
NB	Narrowband
No.	Number
NPÚ	National Heritage Institute, Czech Republic
pFTIR	portable Fourier-transform infrared (spectroscopy)
pFTNIR	Fourier-transform near infrared (spectroscopy)
pRaman	portable Raman (spectroscopy)
pXRF	portable X-Ray Fluorescence
RGB	Red-Green-Blue
RH	Relative Humidity

SEM	Scanning Electron Microscopy
St	Saint
TH Köln	Technische Hochschule Köln
ÚDU AV ČR	Institute of Art History, Czech Academy of Sciences
UPCE FR	University of Pardubice, Faculty of Restoration
UV	Ultraviolet
UVL	Ultraviolet luminescence
UVR	Ultraviolet reflectance
UVRFC	Ultraviolet reflectance false colour
WP	Work Package
µRS	micro Raman Spectroscopy
µFTIR	micro Fourier Transform Infrared Spectroscopy
µXRD	micro-X-Ray Diffraction

DBU-Project "Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague" (AZ 38228/01)

Final Report

Appendix

TH Köln – Technische Hochschule Köln, Cologne Institute of Conservation Sciences

Person in charge of the project and TH Köln Team: Adrian Heritage

Members: Rebecca Tehrani, Dennis Mitschke

Students: Clara Camila Kolny, Karoline Reck, Ava Lina Scharffe, Chari-Juliane Tihanyi

UPCE FR – University of Pardubice, Faculty of Restoration in Litomyšl

Person in charge of the UPCE Team: Jan Vojtěchovský

Members: Karol Bayer, Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, David Svoboda

Students: Radka Farská, Simona Kubasová, Eliška Matoušková, Juliána Tkáčová, Timea Töröková

ABK Stuttgart – Staatliche Akademie der Bildenden Künste Stuttgart

Person in charge of the ABK Stuttgart Team: Roland Lenz

Members: Katharina Schellbach, Judit Zöldföldi, Annette T. Keller

Students: Sarah Ederer, Rosalie Krohm, Hannah Krull, Ronja Löbowitz, Annika Remmele

Beginning of the project: January 2023
Project duration: 39 months (36 months and 3 months cost-neutral extension)
Reporting Period: 39 months

Prague, June 2026

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Author Information

Lead authors

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- ABK Stuttgart: Roland Lenz, Katharina Schellbach

Contributors

- for TH Köln: Dennis Mitschke (ABC Method)
- for UPCE FR: David Svoboda (Spectral Imaging), Kateřina Kubínová (Institute of Art History, Czech Academy of Sciences), Jiří Vidman (Photogrammetry), Jan Sládek (Web Design), Jaroslav Valach and Marek Eisler (IR Thermography)
- for ABK Stuttgart: Judit Zöldföldi (Materials Testing Institute of the University of Stuttgart), InsiTUMlab of the Technical University of Munich with Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann

Appendix

The present Appendix complements the final report of the DBU-funded project *Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague* (AZ 38228/01). It provides supplementary information on the project objectives, organisation, methods, and selected results. The Appendix is structured primarily according to the project work packages and indicates the corresponding chapters of the final report to which the individual sections relate.

The project was carried out between January 2023 and March 2026 by a team from TH Köln, the University of Pardubice (UPCE), and the State Academy of Fine Arts Stuttgart (ABK Stuttgart), in cooperation with Emmaus Abbey and the National Heritage Institute (NPÚ) of the Czech Republic. It focused on the medieval wall paintings in the cloister of Emmaus Abbey and aimed to develop recommendations for their long-term safeguarding, conservation, maintenance, and management of the Emmaus Cycle.

1 Project Outline

→ Corresponding chapters in the final report: Chapter 1.3 Project Objectives; Chapter 2 Work Steps and Method.

1.1 Project Objectives

The following list shows the detailed objectives described in the project application:

1) Digitising and cataloguing previously unrecorded historical documents and archival material relating to the wall painting cycle and its conservation history.
2) Recording and documenting the current condition of the wall paintings, including the extent and character of deterioration phenomena and the assessment of external influences, particularly air pollutants of anthropogenic origin.
3) Conducting climate and environmental monitoring and assessing the current conditions affecting the wall paintings, including the types, causes and sources of deterioration, past environmental influences based on archival material and in-situ evidence, and the potential effects of global climate change and urban pollutants.
4) Distinguishing the original wall paintings from later overpainting through a qualified and area-specific assessment, including the identification of areas in which historical overpainting had been retained during previous restoration campaigns.
5) Differentiating and systematically describing previous restoration measures applied to individual sections of the wall painting cycle, including the identification and evaluation of earlier interventions in relation to future conservation requirements.
6) Combining a range of non-invasive examination methods, including spectral imaging using the Rainbow system, portable X-ray fluorescence analysis (pXRF), portable Raman spectroscopy (pRS), portable Near-infrared spectroscopy (pNIRS), portable Fourier transform near infrared spectroscopy (pFT-IR) and hyperspectral imaging (HSI) in order to optimise the investigative results while minimising the need for physical sampling.
7) Assessing anthropogenic influences affecting the optical and material condition of the wall paintings, including historical overpainting, historical and current air pollutants, war damage, redesign interventions by the Beuron School in the early twentieth century, restoration campaigns from the 1930's to the1960s, and changes since the last comprehensive restoration campaign.

8) Implementing the ABC method for the wall paintings in their architectural context within the cloister of the Emmaus Abbey, integrating the assessment of cultural values with anthropogenic and environmental risk assessment as a basis for a risk management plan, that provides a foundation for the preventive conservation and safeguarding recommendations.
9) Preparing comprehensive documentation to support future development of a Conservation Plan, including recommendations for risk management and emergency preparedness, preventive conservation measures, maintenance, and stabilisation interventions for the wall painting cycle. This documentation will provide the necessary basis for future decisions by the responsible heritage authorities and for the planning of subsequent conservation and management measures.
10) Organising an international colloquium addressing issues of conservation, safeguarding, presentation and maintenance of the wall painting cycle, with the results and conclusions intended to inform the development of preventive conservation and safeguarding recommendations.
11) Disseminating the project results through publications in international specialist journals and through a final English-language publication documenting both the colloquium and the principal outcomes of the project.
12) Making selected photographic and graphic project documentation accessible to the public through the Emmaus Abbey website, supported by a 3D model or equivalent spatial presentation of the cloister.

1.2 Overview of Work Packages

Table 1 provides an overview of the work packages and the corresponding responsibilities as described in the project application. The following chapters are structured accordingly.

Table 1: Detailed Overview of the work packages, including lead responsibility, participating partners and duration in months, DBU-funded project AZ 38228/01.

#	Work package (WP)	Lead	Partners	Duration
1	**Project Management** *Management and coordination of individual project parts, coordination of cooperation between project partners. Organisation of project meetings, preparation of interim and final reports. Financial management of the project.*	TH Köln	UPCE, ABK Stuttgart	36 +3
2	**Research, Processing of the Archive Material, and Literature Research** *Systematic search, compilation and evaluation of all available published and archival materials in connection with the wall painting cycle. Detailed archival research on all cycle wall paintings in 4 archives, possibly supplemented by further research arising from the results, subsequent cataloguing.*	UPCE	ABK Stuttgart	12
3	**Visual Examination, Characterisation and Mapping of Individual Phenomena** *Visual examination of 26 paintings including detailed photo documentation (documentary photography, macro photography, micro photography), recording of phenomena of the original painting technique, interventions and damage based on photo documentation or photogrammetry on 26 paintings.*	UPCE	ABK Stuttgart, TH Köln	28
4	**Investigation of Selected Areas Using Non-Invasive Imaging Techniques** *Examination using imaging techniques: classic documentation photography, microphotography, technical photography. Spectral imaging, especially in the VIS, UV and IR ranges, with multi- and narrowband spectral photography (Phase One Rainbow System) and also IR-Thermography on selected 5 painting areas. Subsequent computer analysis and image processing.*	ABK Stuttgart	UPCE, TH Köln	8
5	**Investigation of Selected Areas Using Non-Invasive Analytical Methods**. *Investigation of material composition in selected areas using mobile X-ray fluorescence analysis and NIR and Raman spectroscopy.*	ABK Stuttgart	TH Köln, UPCE	16

#	Work package (WP)	Lead	Partners	Duration
6	**Environmental Assessment, Climate Monitoring and Implementation of the ABC Risk Assessment Method** *Environmental assessment of the wall paintings in their context to evaluate the past and present impact of sources of damage. This will involve analysing the environment and the "Agents of Deterioration", including physical forces, fire, water, incorrect temperature, incorrect relative humidity, light, pollutants, etc., and their potential to contribute to future risks. Climate data loggers will be installed in the cloister to collect qualitative and quantitative environmental data during the project. This includes the continuous measurement of the air and surface temperature of the painting as well as the relative humidity at selected points in the cloister and the exterior of the Abbey throughout the project. Furthermore, the climate and air quality data of the last 10 years will be analysed in order to contextualize the new project-specific measurements. Implementation of the ABC Method (CCI/ICCROM), a risk assessment tool designed to identify and prioritise risks to cultural heritage, with the aim of achieving the best possible long-term preservation while respecting the cultural significance of the site and its wall paintings within the resources available. By combining cultural values assessment with anthropogenic and environmental risk assessment, the project necessarily requires both multidisciplinary and interdisciplinary contributions from the project partners and external consultants. Equally important is broad consultation with a diverse range of stakeholders, including site managers, heritage authorities, local communities, and national decision-makers, whose perspectives are essential to developing a realistic and sustainable conservation framework.*	TH Köln	ABK Stuttgart, UPCE	36
7	**Material Analysis with Invasive Analytical Methods** *Based on the results of the investigation using non-invasive methods, areas for sampling are determined for further material analyses. The analyses will focus on the stratigraphy and composition of the original paintings as well as on the underlying plaster layers and later interventions. The results should also contribute significantly to the assessment of the condition and determination of the probable causes of damage. The samples will be analysed using the following methods: Optical microscopy (OM) and scanning electron microscopy with EDS analysis (SEM-EDS), gas chromatography coupled mass spectroscopy (GCMS), micro-Fourier transform infrared spectroscopy (micro-FTIR), micro Raman spectroscopy (µRS).*	UPCE	ABK Stuttgart, TH Köln	22
8	**Comprehensive Comparison and Evaluation of the Results of All Parts of the Survey and Recording** *Complex evaluation of all investigations, preparation of investigation reports and documents for the final international colloquium. Final and summarising evaluation of the project results, including the development of recommendations for the future conservation, preventive care, monitoring and maintenance of the wall painting cycle.*	UPCE	ABK Stuttgart, TH Köln	13
9	**Preparation and Organisation of the International Colloquium** *Organisation of an international colloquium to present and discuss the research results. As part of the colloquium, the results of other research work, investigations and experiences with examination, conservation and restoration, safeguarding and preservation for similar wall paintings at other locations in the European cultural environment will also be presented.*	UPCE	ABK Stuttgart, TH Köln	6

2 WP 1: Project Management

→ *Corresponding chapter in the final report: Chapter 2.2 Project Management (WP1).*

Prior to the commencement of the project, the partners agreed to postpone the start date from 27 September 2022 to 2 January 2023. This allowed sufficient time for all partners to advertise and appoint project staff and aligned the project with the beginning of the financial year. The revised start date was approved by all project partners and the DBU.

During the project period (January 2023–March 2026), regular online meetings, in-person meetings in Prague and Cologne, and numerous on-site campaigns were undertaken. Many of the on-site campaigns were accompanied by students from the three participating universities (Figure 1).

Following the formal completion of the project in March 2026, the project team continued to meet regularly online to coordinate the preparation of the final publication and completion of the final report. In accordance with the DBU reporting requirements, the final report was submitted within the prescribed three-month period following the project's completion.

Over the course of the project, five interim monitoring reports were submitted at six-month intervals. Minutes of the project meetings accompanied these reports and were submitted to the DBU. They are not reproduced in the present Appendix, which is intended for online publication and therefore excludes internal project documentation containing personal or confidential information.

The following sections provide an overview of the reporting periods, project meetings, and on-site campaigns.

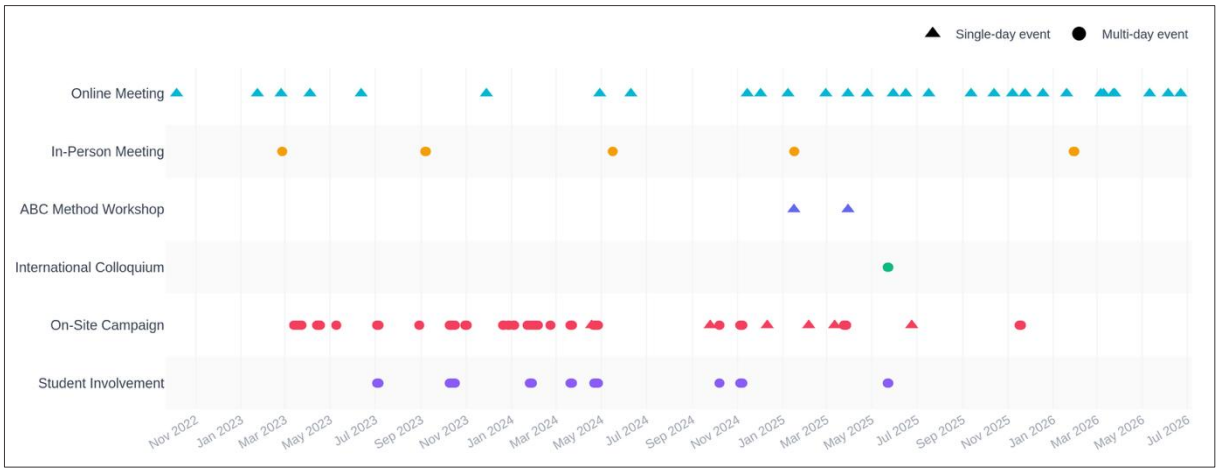


Figure 1: Overview of online meetings, in-person meetings, ABC Workshops, the International Colloquium, student involvement and on-site campaigns (October 2022-June 2026); DBU-funded project AZ 38228/01. Graphic ©Rebecca Tehrani, David Riedel 2026.

2.1 Reporting period

- First Interim Monitoring Report, submitted June 2023
- Second Interim Monitoring Report, submitted December 2023
- Third Interim Monitoring Report, submitted June 2024
- Fourth Interim Monitoring Report, submitted December 2024
- Fifth Interim Monitoring Report, submitted June 2025
- Final Report, submitted June 2026

2.2 Online Meetings

During the project period and the subsequent reporting phase, thirty online meetings were held. The dates of the meetings and the participating project partners are listed in the table below.

Table 2: Online meetings between January 2023 and June 2026, DBU-funded project AZ 38228/01.

Online Meeting	Date	Time	Attendees
1	**06.10.2022**	14:00	Karol Bayer, UPCE; Romana Cermanová, DBU; Adrian Heritage, TH Köln; Roland Lenz, ABK Stuttgart; Jan Vojtechovsky, UPCE.
2	**23.01.2023**	15:30-16:30	Romana Cermanová, DBU; Adrian Heritage, TH Köln; Roland Lenz, ABK Stuttgart; Jan Vojtechovsky, UPCE.
3	**24.02.2023**	09:15-11:15	Karol Bayer, UPCE; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Adrian Heritage, TH Köln; Katharina Schellbach, ABK Stuttgart; Ava Lina Scharffe, TH Köln; Chari Juliane Tihanyi, TH Köln; Jiří Vidman, contracted for UPCE; Jan Vojtěchovský, UPCE.
4	**04.04.2023**	14:00-16:20	Karol Bayer, UPCE; Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Jan Vojtechovsky, UPCE.
5	**12.06.2023**	10:00-12:00	Karol Bayer, UPCE; Romana Cermanová, DBU; Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Katharina Schellbach, ABK Stuttgart; Jan Vojtechovsky, UPCE.
6	**28.11.2023**	09:30-11:30	Karol Bayer, UPCE; Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Jan Vojtechovsky, UPCE.
7	**29.04.2024**	10:00-12:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE; Judit Zöldföldi, ABK Stuttgart.
8	**10.06.2024**	11:00-13:00	Karol Bayer, UPCE; Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE; Judit Zöldföldi, ABK Stuttgart.
9	**14.11.2024**	15:00-17:00	Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.
10	**02.12.2024**	09:00-10:15	Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE, Judit Zöldföldi, ABK Stuttgart (JZ).
11	**08.01.2025**	09:00-11:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE; Judit Zöldföldi, ABK Stuttgart (JZ).
12	**28.02.2025**	15:00-17:00	Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.
13	**30.03.2025 ABC Workshop Part II**	10:00-12:00	Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE; Judit Zöldföldi, ABK Stuttgart. External workshop participants: Petra Hoftichová, NPU Praha.
14	**25.04.2025**	15:00-16:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.
15	**30.05.2025**	10:00-11:15	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.
16	**16.06.2025**	10:00-11:15	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.

Online Meeting	Date	Time	Attendees
17	**17.07.2025**	10:00-11:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE; Judit Zoeldfoeldi, ABK Stuttgart.
18	**12.09.2025**	09:00-10:30	Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart); Petra Lesniaková, UPCE; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
19	**13.10.2025**	11:00-12:30	Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
20	**07.11.2025**	15:00-16:30	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Radka Velebilová, graphic designer; Jan Vojtěchovský, UPCE.
21	**24.11.2025**	11:00-12:30	Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
22	**18.12.2025**	10:00-11:30	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Radka Velebilová, graphic designer; Jan Vojtěchovský, UPCE.
23	**19.01.2026**	14:00-16:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Radka Velebilová, graphic designer; Jan Vojtěchovský, UPCE.
24	**06.03.2026**	08:00-10:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
25	**10.03.2026**	15:00-17:00	Adrian Heritage, TH Köln; Roland Lenz, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
26	**23.03.2026**	09:00-11:00	Adrian Heritage, TH Köln; Roland Lenz, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
27	**25.03.2026**	14:00-16:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.
28	**11.05.2026**	10:00-12:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Dennis Mitschke, TH Köln; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
29	**05.06.2026**	09:00-11:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Kateřina Krhánková, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Katharina Schellbach, ABK Stuttgart; Rebecca Tehrani, TH Köln; Jan Vojtěchovský, UPCE.
30	**22.06.2026**	12:00-14:00	Adrian Heritage, TH Köln; Daniela Jakubů, UPCE; Roland Lenz, ABK Stuttgart; Petra Lesniaková, UPCE; Rebecca Tehrani, TH Köln; Jan Vojtechovsky, UPCE.

2.3 In-Person Project Meetings

Over the course of the project, five in-person project meetings were held, each lasting several days. Four meetings took place at Emmaus Abbey in Prague and were coordinated by the UPCE project team, while the fifth meeting was hosted by TH Köln in Cologne. External cooperation partners, together with representatives of the DBU and the NPÚ, were regularly invited to participate in these meetings.

1st Project Meeting, 24-25 February 2023, Emmaus Abbey, Prague

The first project meeting served as the initial in-person coordination meeting of the project partners and focused on introducing the participating institutions, team members, and their respective roles within the project.

The meeting addressed the overall timetable, the implementation of individual work packages, and the coordination of survey methods and tools for their suitable application in the cloister. Further

discussions concerned photogrammetric documentation, documentation standards, imaging requirements, numbering systems, and the preparation of future survey campaigns.
The afternoon session involved representatives of the National Heritage Institute and the Czech Academy of Sciences. It included a presentation of the project aims, structure, and methods to the external participants, followed by a joint inspection of the wall paintings in the cloister. Selected wall painting bays were observed from the mobile scaffolding in order to discuss access, survey conditions, and potential areas for more intensive imaging and investigation. On 25 February 2023, further on-site inspections and preparatory survey activities were carried out, including discussions on scaffold requirements and potential locations for environmental monitoring equipment.

Project team	Karol Bayer, Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, Jan Vojtěchovský (University of Pardubice); Adrian Heritage, Ava Lina Scharffe, Chari Juliane Tihanyi (TH Köln); Roland Lenz, Katharina Schellbach (ABK Stuttgart).
Online participants	Annette Keller (ABK Stuttgart); Dennis Mitschke (Bamberg University / TH Köln); Judit Zöldföldi (MPA University of Stuttgart / ABK Stuttgart)
Institutional representatives and specialists	Petra Hoftichová, National Heritage Institute, Prague; Kateřina Kubínová, Czech Academy of Sciences, Institute of Art History; Jiří Vidman, photogrammetry specialist, contracted for the University of Pardubice; Daniela Zemanová, National Heritage Institute, General Directorate.

2nd Project Meeting, 6-8 September 2023, Emmaus Abbey, Prague

The second project meeting focused on the presentation and discussion of interim results from the first project phase and on the coordination of the next steps within the individual work packages.
The meeting addressed the progress of the archival research, the visual survey, technical photography and spectral imaging, photogrammetry, thermography, and environmental monitoring. Further discussions concerned the selection of suitable areas for further imaging and analytical investigation, including the *Phase One* Rainbow System survey and the practical requirements for carrying out this survey in the cloister, the use of photogrammetric and thermographic outputs, the phenomena catalogue, documentation procedures, and the organisation of project data.
The meeting also involved discussions with representatives of the National Heritage Institute on findings and questions relating to the building and restoration history of the cloister. On-site inspections were carried out in the cloister, including observations of selected wall painting bays from the mobile scaffolding. These inspections supported the discussion of individual phenomena, survey conditions, scaffold requirements, and further work-package planning.

Project team	Karol Bayer, Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, David Svoboda, Jan Vojtěchovský (University of Pardubice); Adrian Heritage, Chari Juliane Tihanyi (TH Köln); Roland Lenz, Katharina Schellbach (ABK Stuttgart)
Institutional representatives and specialists	Petra Hoftichová, National Heritage Institute, Prague; Kateřina Kubínová, Czech Academy of Sciences, Institute of Art History; Jaroslav Valach, Czech Academy of Sciences, Institute of Theoretical and Applied Mechanics; Jiří Vidman, photogrammetry specialist, subcontractor for the UPCE.

3rd Project Meeting, 16-17 May 2024, Emmaus Abbey, Prague

The third in-person project meeting took place at Emmaus Abbey in Prague from 16 to 17 May 2024. It focused on the presentation and discussion of interim results by the project partners and specialists involved in the project, as well as on the coordination of further investigations and subsequent work steps.
The meeting addressed results from the *Phase One* Rainbow System survey, non-invasive instrumental investigations, the archive survey, the visual survey, technical photography and spectral imaging, photogrammetry, thermography, environmental monitoring, the liquid moisture survey, and the planned application of the ABC method. Further discussions concerned proposed sampling areas, related research questions, surveying strategies and the planning of subsequent project steps.
The meeting also included discussions on the project colloquium, including its date, structure, possible contributions, and the involvement of project partners, external speakers, DBU representatives, and representatives of the Abbey. In this context, the use of a questionnaire for monks and Abbey staff was discussed in order to gather views on the future presentation of the wall paintings.
On-site discussions in the cloister and from the mobile scaffolding allowed the team to observe and discuss the wall paintings directly. Further topics included the possible use of selected orthophotos and image results in a 3D model, as well as the planning of subsequent meetings and campaigns.

Project team	Adrian Heritage, Rebecca Tehrani (TH Köln); Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, David Svoboda, Jan Vojtěchovský (UPCE); Roland Lenz, Katharina Schellbach, Judit Zöldföldi (ABK Stuttgart).
DBU representative	Constanze Fuhrmann
Institutional representatives and specialists	Marek Eisler and Jaroslav Valach, thermography specialists, Czech Academy of Sciences, Institute of Theoretical and Applied Mechanics, contracted for the University of Pardubice; Kateřina Kubínová, Czech Academy of Sciences, Institute of Art History; Jiří Vidman, photogrammetry specialist, contracted for UPCE.

4th Project Meeting, 16-17 January 2025, Emmaus Abbey, Prague

The first day of the fourth in-person project meeting was devoted to the first part of the ABC Method Workshop, led by Dennis Mitschke. The workshop introduced the ABC Method, established the context for the risk assessment, identified and discussed potential risks, and considered aspects relevant to the preliminary investigation. It also examined the values associated with the wall painting cycle and included a discussion of presentation issues with invited participants.
The remainder of the first day focused on updates to the ongoing project work, including mapping and graphic documentation, the imaging and non-invasive analytical campaign, and the results of material sampling. Further discussions addressed conservation and presentation issues, including lighting, the visual impact of previous conservation interventions, and the appearance of historic repairs and surface coatings.
The second day was devoted to coordinating the remaining project activities and presenting further interim results. Topics included the development of the project website, the organisation of historical and newly acquired image material, sampling, environmental and microclimate monitoring, and preparations for the project colloquium. Further discussions addressed the structure and logistics of the colloquium, initial planning for the final publication, research data management, and the remaining steps towards project completion.

Project attendees	Adrian Heritage, Dennis Mitschke, Rebecca Tehrani (TH Köln); Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, Jan Vojtěchovský (UPCE); Roland Lenz, Katharina Schellbach, Judit Zöldföldi (ABK Stuttgart).
External workshop attendees	Barbora Glombová, restorer; Jan Fiřt, National Heritage Institute, Prague; Kateřina Kubínová, Czech Academy of Sciences; Petra Hoftichová, National Heritage Institute, Prague; Barbora Uchytilová, Czech Academy of Sciences; Markéta Vlková, National Heritage Institute, Prague; Tomáš Váňa, restorer.
Institutional representatives and specialists	Jan Sládek, website programmer; Jiří Vidman, photogrammetry specialist, subcontractor for the UPCE.

5th Project Meeting, 28-30 January 2026, TH Köln, Cologne

The final in-person project meeting focused on the coordination of the final project phase and on the synthesis of the project results as a basis for the development of recommendations and a strategic framework as a basis for future decision-making and conservation planning.

The meeting addressed topic-led discussions in which the results from the different work packages were brought together and discussed with regard to future decision-making, preventive conservation, risk management, monitoring, testing, and possible phased implementation. Further topics included the final publication, the project website, and the final report.

Further discussions concerned the publication layout, print production, review process, payment for external services, updated schedule, and instructions to authors. The meeting also included a small group discussion on the contribution for the final publication and a guided visit to Cologne Cathedral and the choir screen paintings, during which Adrian Heritage gave an introduction to the wall paintings.

Project attendees	Adrian Heritage, Dennis Mitschke, Rebecca Tehrani (TH Köln); Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, Jan Vojtěchovský (UPCE); Roland Lenz, Katharina Schellbach, Judit Zöldföldi (ABK Stuttgart).
Contributor	Tanja Pinkale, guided visit to the Cologne Cathedral

2.4 On-site Campaigns and Project-Related Visits

The following table (Table 3) summarises the on-site campaigns and project-related visits carried out during the project period. The overview includes preparatory visits, survey campaigns, technical and photographic documentation, environmental assessment, non-invasive and analytical investigations, sampling, monitoring, and student campaigns and involvement.

Table 3: Overview of on-site Campaigns and Project-Related visits, DBU-funded Project (AZ/38228/01).

Date	Purpose	Attendees
12 Jan 2023	Preparatory meeting of the FR UPa / UPCE team at Emmaus Abbey; initial discussions, preparation, and first survey	FR UPa / UPCE team
10 Mar 2023	Test of spectral imaging	Petra Lesniaková, David Svoboda (UPCE)
13–24 Mar 2023	Visual Survey, cleaning of spider webs on the West and North walls; research on site	Daniela Jakubů, Kateřina Krhánková, Jan Vojtěchovský (UPCE); Katharina Schellbach (ABK Stuttgart)
	Preparation and realisation of spectral imaging on Bay 10	Jan Vojtěchovský, Petra Lesniaková, David Svoboda (UPCE)

Date	Purpose	Attendees
	Photogrammetry of the North and West walls	Jiří Vidman, contracted by UPCE
13–14 Apr 2023	Cleaning of spider webs on the South wall; continuation of spectral imaging	Daniela Jakubů, Kateřina Krhánková, Jan Vojtěchovský (UPCE)
	Photogrammetry of the South wall	Jiří Vidman, contracted by UPCE
14–18 Apr 2023	Cleaning of spider webs on the East wall; continuation of spectral imaging and photographic documentation	Daniela Jakubů, Kateřina Krhánková, Jan Vojtěchovský; David Svoboda (UPCE)
	Photogrammetry of the East wall	Jiří Vidman, contracted by UPCE
9–10 May 2023	Thermography, visual survey, and UV luminescence survey	Jan Vojtěchovský, David Svoboda (UPCE); Jaroslav Valach and Marek Eisler, Czech Academy of Sciences, Institute of Theoretical and Applied Mechanics
3–6 Jul 2023	Liquid moisture survey	Adrian Heritage (TH Köln) Chari-Juliane Tihanyi, Ava Lina Scharffe, Karolina Reck, Clara Kolny (TH Köln students)
29–30 Aug 2023	On-site visual investigation, survey	Daniela Jakubů, Jan Vojtěchovský (UPCE)
9–17 Oct 2023	On-site visual investigation, survey and documentation	Daniela Jakubů, Jan Vojtěchovský (UPCE); Radka Farská, Simona Kubasová and Juliána Tkáčová (UPCE students)
30 Oct–2 Nov 2023	On-site visual investigation, survey and documentation	Daniela Jakubů, Jan Vojtěchovský (UPCE)+
20–22 Dec 2023	pXRF measurement	Petra Lesniaková (UPCE)
27–29 Dec 2023	pXRF measurement	Petra Lesniaková (UPCE)
03–05 Jan 2024	pXRF measurement	Petra Lesniaková (UPCE)
22 Jan–6 Feb 2024	Multispectral imaging campaign using the Rainbow System	Annette T. Keller, contracted by ABK Stuttgart; Katharina Schellbach, Roland Lenz (ABK Stuttgart)
25–29 Jan 2024	Liquid moisture survey, data logger installation, and risk assessment	Adrian Heritage, Chari-Juliane Tihanyi (TH Köln); Dennis Mitschke, contracted by TH Köln
22 Feb 2024	Research, technical photography, and photographic documentation	Daniela Jakubů, Petra Lesniaková, David Svoboda, Jan Vojtěchovský (UPCE)
23 Feb 2024	Research	Daniela Jakubů, Jan Vojtěchovský (UPCE)
20–23 Mar 2024	BA research: liquid moisture survey	Chari-Juliane Tihanyi (TH Köln)
20 Apr 2024	pXRF measurement	Petra Lesniaková (UPCE)
18 Apr 2024	Research on painting technique and photography	Petra Lesniaková, David Svoboda, Jan Vojtěchovský (UPCE)
21–25 Apr 2024	Non-invasive instrumental investigation, including NIR and Raman spectroscopy, for the identification of pigments, salts, alteration products, and conservation materials	Katharina Schellbach, Judit Zöldföldi (ABK Stuttgart)
21–27 Apr 2024	BA research: liquid moisture survey and environmental assessment	Adrian Heritage, Chari-Juliane Tihanyi, Rebecca Tehrani (TH Köln)
25 Sep 2024	Sampling	Daniela Jakubů, Petra Lesniaková, Jan Vojtěchovský (UPCE)
27 Sep 2024	pXRF measurement	Petra Lesniaková (UPCE)
7–8 Oct 2024	Student campaign: on-site investigation, survey, documentation, and mapping	Daniela Jakubů (UPCE), Eliška Matoušková, Timea Töröková (UPCE students)
5 Nov 2024	Sampling	Daniela Jakubů, Petra Lesniaková, Jan Vojtěchovský (UPCE)
4–8 Nov 2024	Student campaign: on-site investigation, survey, documentation, and mapping	Daniela Jakubů (UPCE), Eliška Matoušková, Timea Töröková (UPCE students); Roland Lenz, Katharina Schellbach (ABK Stuttgart); Sarah Ederer, Rosalie Krohm, Hannah Krull, Ronja Löbowitz, Annika Remmele (ABK Stuttgart students)
11 Dec 2024	On-site investigation, survey, documentation, and mapping	Daniela Jakubů, Jan Vojtěchovský (UPCE)
05 Feb 2025	Sampling	Daniela Jakubů, Petra Lesniaková, Jan Vojtěchovský (UPCE)
12 Mar 2025	Sampling	Daniela Jakubů, Petra Lesniaková, Jan Vojtěchovský (UPCE)

Date	Purpose	Attendees
24–28 Mar 2025	Non-destructive analyses with hyperspectral imaging and spot analysis, in collaboration with colleagues from InsiTUMLab	Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, Jan Vojtěchovský (UPCE); Roland Lenz, Katharina Schellbach, Judit Zöldföldi (ABK Stuttgart); Dr Clarimma Sessa, Dr Eva Mariasole Angelin, M.A. Simon Mindermann, Monica Carraro, Erasmus bachelor's student from Italy (InsiTUMLab at the Technical University of Munich)
	Environmental assessment, archival research, and installation of further data loggers	Rebecca Tehrani (TH Köln)
24 Jun 2025	Sampling	Daniela Jakubů, Jan Vojtěchovský (UPCE)
18 Nov 2025	Sampling	Kateřina Krhánková, Petra Lesniaková (UPCE)
16–19 Nov 2025	Dismantling of data loggers and documentation	Rebecca Tehrani (TH Köln), Petra Lesniaková, Kateřina Krhánková (UPCE)

3 WP2: Research, processing of the archive material, and literature research

→ Corresponding chapters in the final report: Chapter 2.3 Research, Processing of the Archive Material, and Literature Research (WP2), Chapter 3.1 Conservation History and Conservation Campaigns

An overview of the number of photographs of each field from each time stage was created. As part of archival research, approximately 900–1,000 historical photographs of wall paintings from the Emmaus Cycle were collected from at least ten archival institutions in the Czech Republic and abroad. The most significant collections include photographs by Karel Bellmann from the late nineteenth century, a collection from 1935 held at the Bildarchiv Foto Marburg, documentation of restoration work in the 1940s, images capturing the aftermath of the 1945 bombing, and postwar conservation interventions. All acquired photographs were geolocated, systematically sorted by individual field and iconographic scenes, and subsequently arranged chronologically (Figure 2).

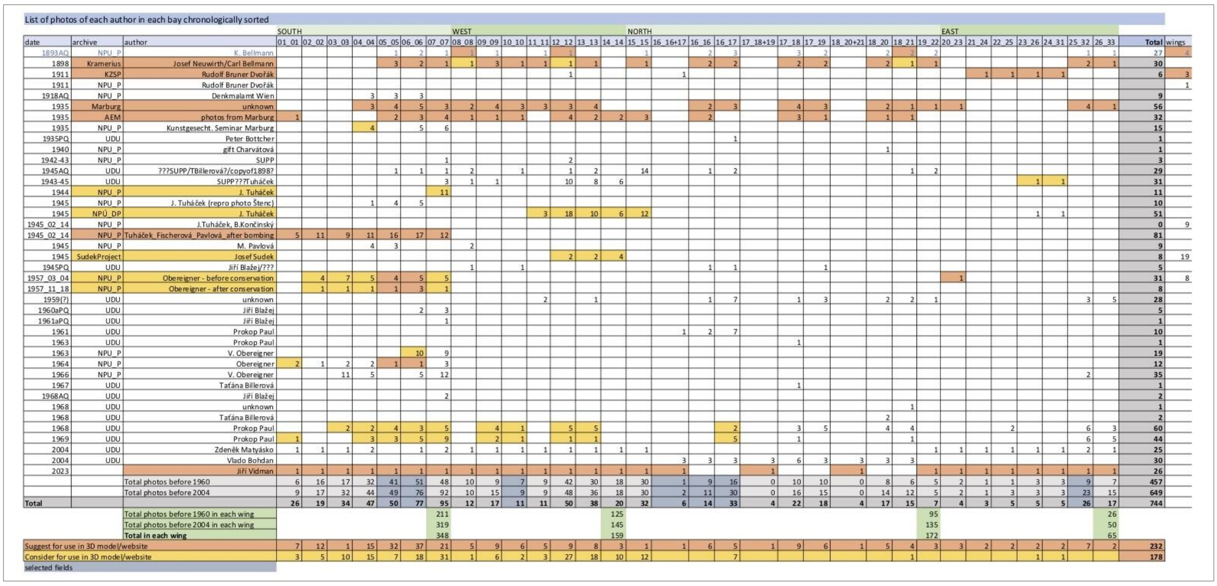


Figure 2: An overview of the number of image graphs of each field from each time stage was created. © Kateřina Krhánková.

For each field, an overview of the photographic documentation across different time periods was created, making it possible to track changes in the condition of the paintings over time and to identify the effects of restoration interventions as well as other historical events. A prime example is field 05(05), for which it was possible to compile an almost continuous photographic series ranging from Bellmann's earliest photographs from before 1893, through documentation from 1935 and photographs taken after the 1945 bombing, to images capturing restoration interventions from the second half of the twentieth century. This temporal continuity represents an exceptionally valuable source for assessing changes in the appearance and condition of the paintings over the course of more than a century. The examples are shown in the figures below (Figure 3, Figure 4, Figure 5, Figure 6).

Where available, each photograph's file name includes the year in which the photograph was taken, the institution holding the archival record, the photographer, the number of the documented field, the original archival name or call number, and any additional notes. For example, the designation: 1945_NPU_P_Tuháček_Fischerová_Pavlová_05_05_N038572_XX_N038572_278 includes the year the photograph was taken (1945), the archive (NPÚ), the photographer (Jan Tuháček), the field designation (05/05), the original archival identification of the photograph (N038572), an additional note and archive ID/photo negative number.

Field 05 (05) - The Virgin Mary Wins over the Devil

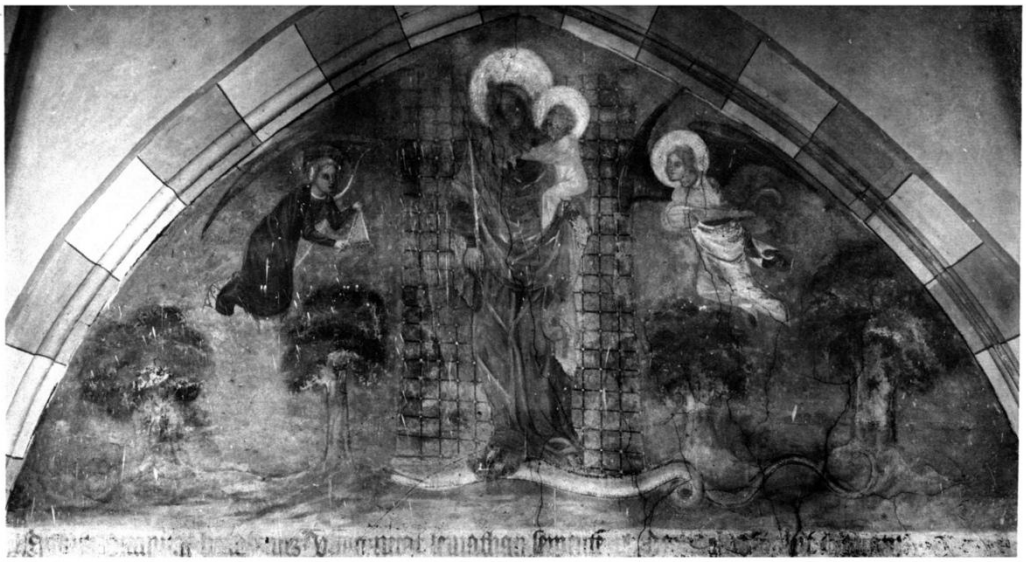


Figure 01. 1898_Neuwirth_05_05_96_Kramerius_X

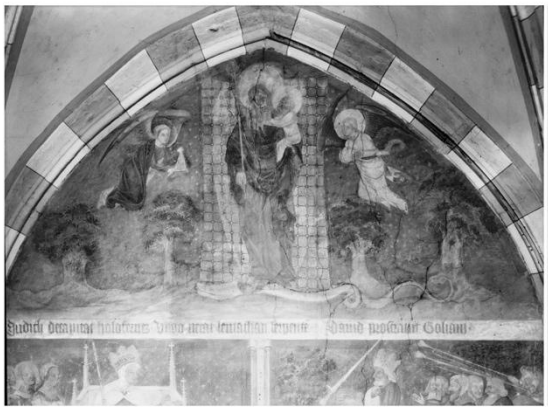


Figure 02. 1935_Marburg_05_05_fm73536_ bildindex_fm73536

Figure 03. 1945_NPU_P_Tuháček_Fischerová_ Pavlová_05_05_N038572_XX_N038572_278

Figure 04. 1957_NPU_P_Obereigner_05_05_ N076046_XX_N076046_400

Figure 05. 1968_UDU_PPaul_05_05_1552_50_ UP_XX_1552_50_UP

Figure 3: Field 05(05) – The Virgin Mary Wins over the Devil – chronological sequence 1898, 1935, 1945, 1957, 1968. Collage created by Kateřina Krhánková. / ©Marburg, NPÚ GŘ, ÚDU AV (the archives and authors of the photographs are indicated in the individual captions).

Field 05 (05) - Judith with the Head of Holofernes

Figure 06. 1898_Neuwirth_05_05_97_ Kramerius_X

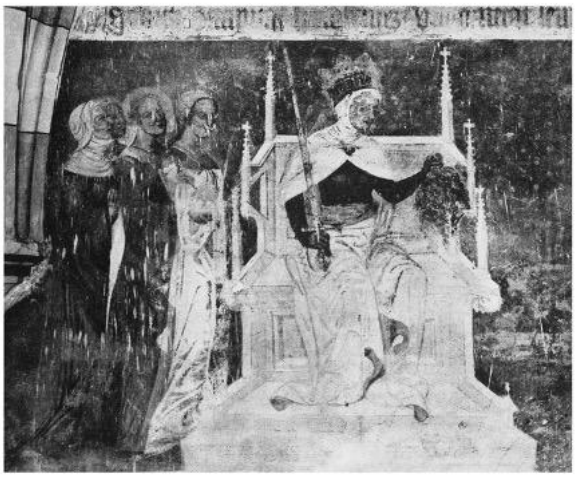


Figure 07. 1935_Marburg_05_05_fm1202684_ bildindex_fm1202684

Figure 08. 1945_NPU_P_Tuháček_ Fischerová_Pavlová_05_05_N038581_XX_

Figure 09. 1957_NPU_P_Obereigner_05_05_ N076047_XX_N076047_402

Figure 10. 1968_UDU_PPaul_05_05_325_21_ 18771_UP_XX_325_21_18771_UP

Figure 4: Field 05(05) – Judith with the Head of Holofernes – chronological sequence 1898, 1935, 1945, 1957, 1968. Collage created by Kateřina Krhánková. / ©Marburg, NPÚ GŘ, ÚDU AV (the archives and authors of the photographs are indicated in the individual captions).

Field 05 (05) - The Virgin Mary Wins over the Devil; Judith with the Head of Holofernes; David with the Head of Goliath

Figure 15. 1935_Marburg_05_05_fm73535_bildindex_fm73535

Figure 16. 1945_NPU_P_Tuháček_Fischerová_Pavlov_05_05_N038517_XX_N038517_208

Figure 17. 1957_NPU_P_Obereigner_05_05_N076045_XX_N076045_398

Figure 19. 1968_UDU_PPaul_05_05_1552_49_UP_XX_1552_49_UP

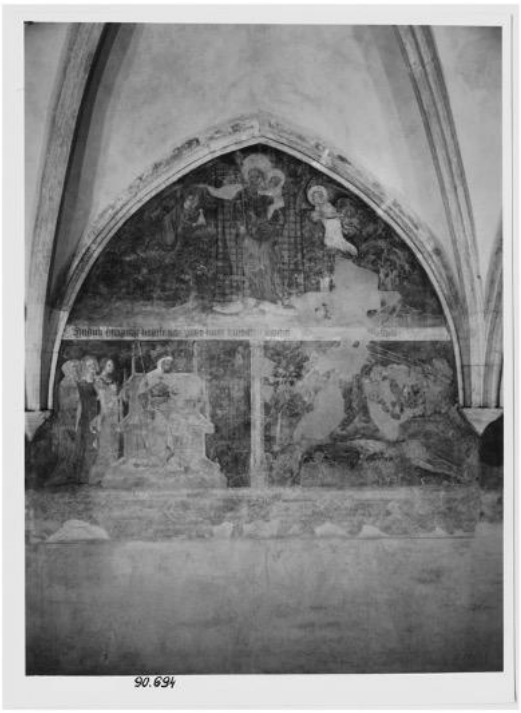


Figure 18. 1964_NPU_P_Obereigner_05_05_N090694_XX_N090694_476

Figure 5: Field 05(05) – The Virgin Mary Wins over the Devil; Judith with the Head of Holofernes; David with the Head of Goliath – chronological sequence 1935, 1945, 1957, 1964, 1968. Collage created by Kateřina Krhánková. / ©Marburg, NPÚ GŘ, ÚDU AV (the archives and authors of the photographs are indicated in the individual captions).

Field 05 (05) - David with the Head of Goliath

Figure 11. 1898_Neuwirth_05_05_98_ Kramerius_X

Figure 12. 1935_Marburg-physical_64883_5c

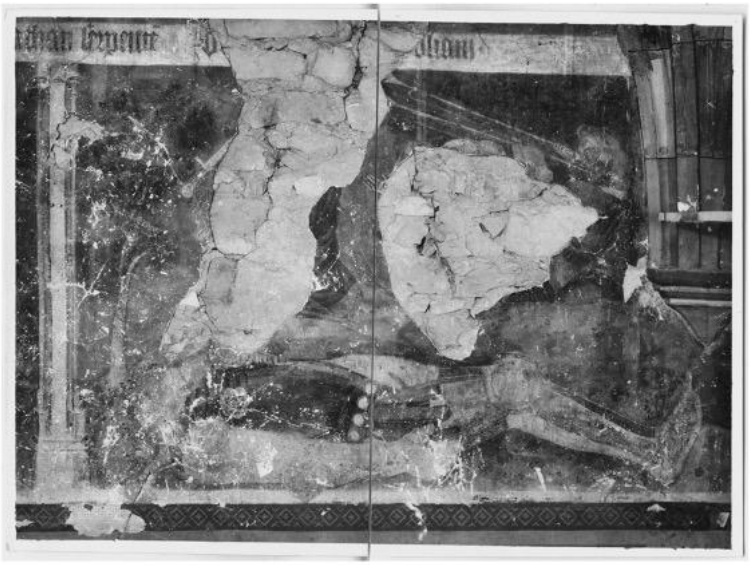


Figure 13. 1945_NPU_P_ Tuháček_Fischerová_Pavlová_05_ 05_N038585_XX_N038585_304

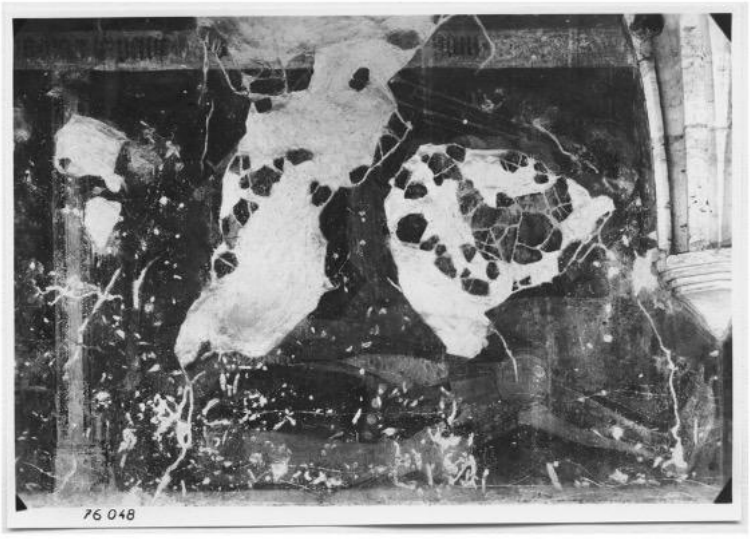


Figure 14. 1957_NPU_P_ Obereigner_05_05_N076048_XX_ N076048_404

Figure 6: Field 05(05) –David with the Head of Goliath – chronological sequence 1898, 1935, 1945, 1957. Collage created by Kateřina Krhánková. / ©Marburg, NPÚ GŘ, ÚDU AV (the archives and authors of the photographs are indicated in the individual captions).

4 WP3: Visual Examination, Characterisation and Mapping of Individual Phenomena

→ Corresponding chapters in the final report: Chapter 2.4 Visual Examination, Characterisation and Mapping of Individual Phenomena (WP3), Chapter 3.2 Painting Technique and Materials, Chapter 3.3. Current Condition and Deterioration Phenomena

Work Package 3 realized by UPCE team in collaboration with ABK included a thorough inspection of the paintings from mobile scaffolding. Photogrammetry was produced by external collaborator Ing. Jiří Vidman for all twenty-six individual bays (Figure 9) as well as the four walls of the cloister (Figure 7, Figure 8) at various resolutions, including shaded relief models (Figure 10). Detailed photographic documentation of individual details was acquired. Furthermore, phenomena related to the original, added and altered materials, the condition of the paintings, and those requiring further intervention or monitoring were described and catalogued. Graphic mappings were carried out to document selected categories of both the original technique and phenomena associated with the state of preservation and potential risks, which also enabled the quantification of the monitored categories and the subsequent calculation of the extent of the preserved original parts of the paintings. The on-site work and subsequent processing spanned the first four monitoring periods and included two student campaigns with UPCE students, one during the second and other during the fourth monitoring period (autumn 2023 and autumn 2024).

4.1 Photogrammetry

Figure 7: Photogrammetric image of the East walk of the cloister. © Jiří Vidman, Pavel Hlavenka.

Figure 8: Photogrammetric image of the South walk of the cloister. © Jiří Vidman, Pavel Hlavenka.

Figure 9: Photogrammetric image, orthophoto, bay 25 (32). © Jiří Vidman, Pavel Hlavenka.

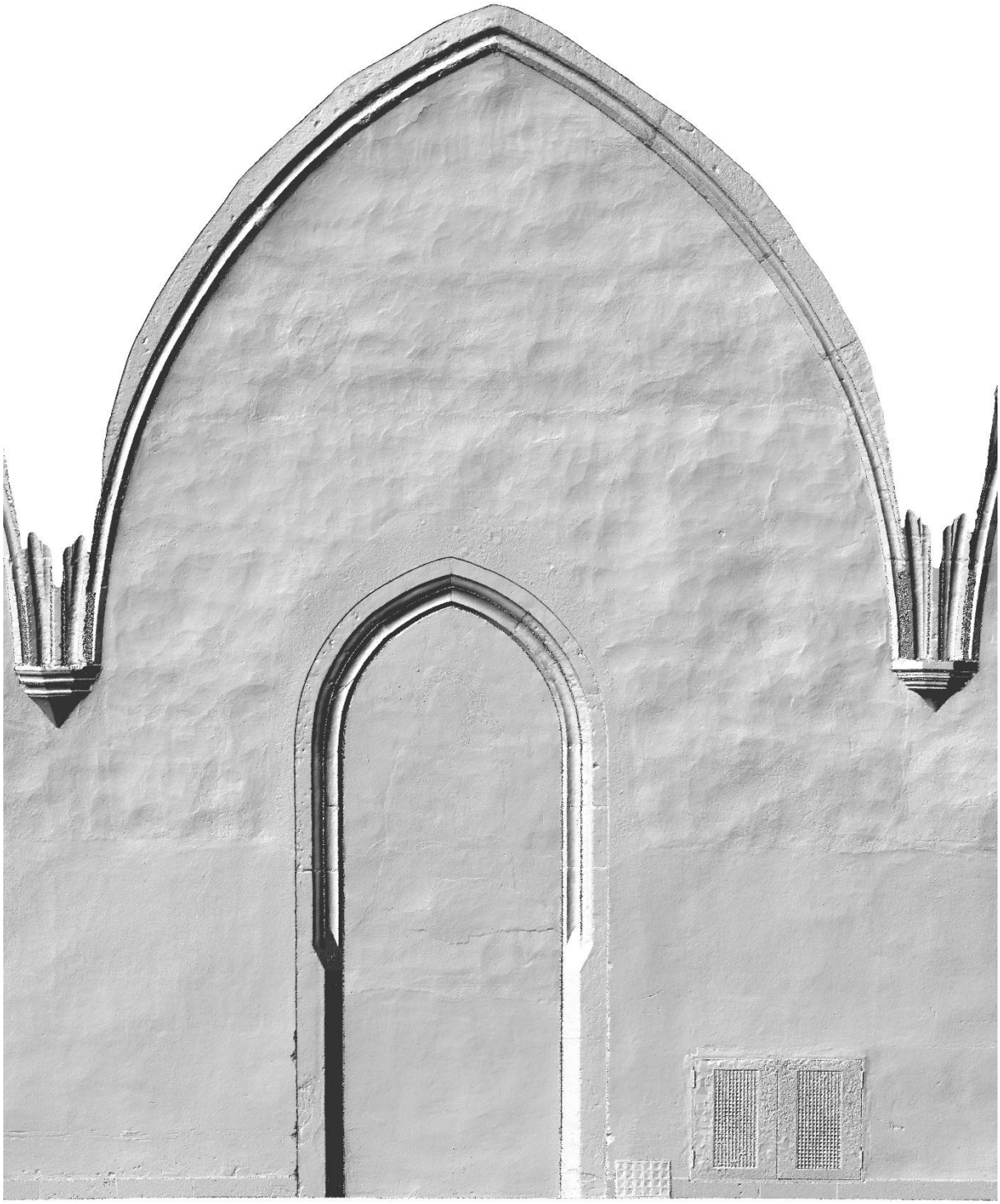


Figure 10: Photogrammetric image, shaded relief, bay 25 (32). © Jiří Vidman, Pavel Hlavenka.

4.2 Catalogue of phenomena

The Catalogue of Phenomena, based on the visual examination conducted on-site, is divided into three sections:

A – original, added, and altered materials
B – condition
C – phenomena for ongoing monitoring and/or treatment

The first section, ***A – original, added, and altered materials***, contains descriptions of 54 phenomena, some of which include multiple examples, totalling 94 pages. It describes the basic properties of the plaster surface and stone architectural elements, as well as the ground, preparatory, and paint layers themselves. Specific features of inscriptional bands (tituli) are also included. In addition to the original materials, the catalogue covers the probable alteration of pigments (e.g., the blackening of certain parts of flesh tones, green tones in the blue background, and dark layers in red sections) and added materials (historical graffiti, several types of historical overpainting, as well as fills and modern retouches). The individual phenomena are arranged primarily spatially, from the substrate and ground layers to the uppermost layers (applications and added layers). Added layers that cannot be ranked relative to each other by depth are listed in a presumed chronological order, ranging from historical additions to the most recent layers from the last conservation treatment in the 1960s.

The second section of the catalogue, ***B – condition***, summarizes the specific state of preservation of the paintings that do not require further monitoring or intervention. This section describes 16 phenomena over 24 pages.

All phenomena related to damage or those potentially leading to further degradation of the paintings are included in the third section, ***C – phenomena*** *for ongoing monitoring and/or treatment*. Eight individual phenomena are presented over 18 pages.

Each phenomenon is listed in only one section of the catalogue, although some could be described in terms of both material and state of preservation (or damage). Phenomena requiring further treatment are listed exclusively in the third section, even though they also represent a condition. Each phenomenon is thus assigned a unique identifier consisting of a letter indicating the catalogue section and a number indicating the sequence within that section (e.g., A1, A2; B1, B2). Each entry also includes a code, which serves as a working folder number for additional images. Finally, information is provided on whether the phenomenon has been included in the graphic mapping.

The catalogue only includes phenomena identified through visual inspection. Other research methods focused on another, potentially hazardous phenomena that are not detectable visually. These primarily involve the presence of voids within the plaster layers and the possible increased concentration of water-soluble salts.

A - original, added and altered materials

Phenomenon: Relief decoration

Number: A35
Code: 071
Location: South walk, bay 3 (3)
Mapping: Yes

Detail image, example A

Description:
Relief decoration is preserved only in the haloes of certain figures in the Last Supper scene (bay 3 (3)) and in the haloes and parts of the angels' wings in bay 1 (1) (example A). Each individual halo consists of several sections. The tin relief technique has been confirmed by laboratory analysis. Traces of gilding are visible on the relief layer, although the gilding is better preserved in its surroundings. A faint imprint of the relief decoration is visible in the Virgin Mary's halo in bay 7 (7) and in the Christ Child's halo in bay 6 (6) (example B).

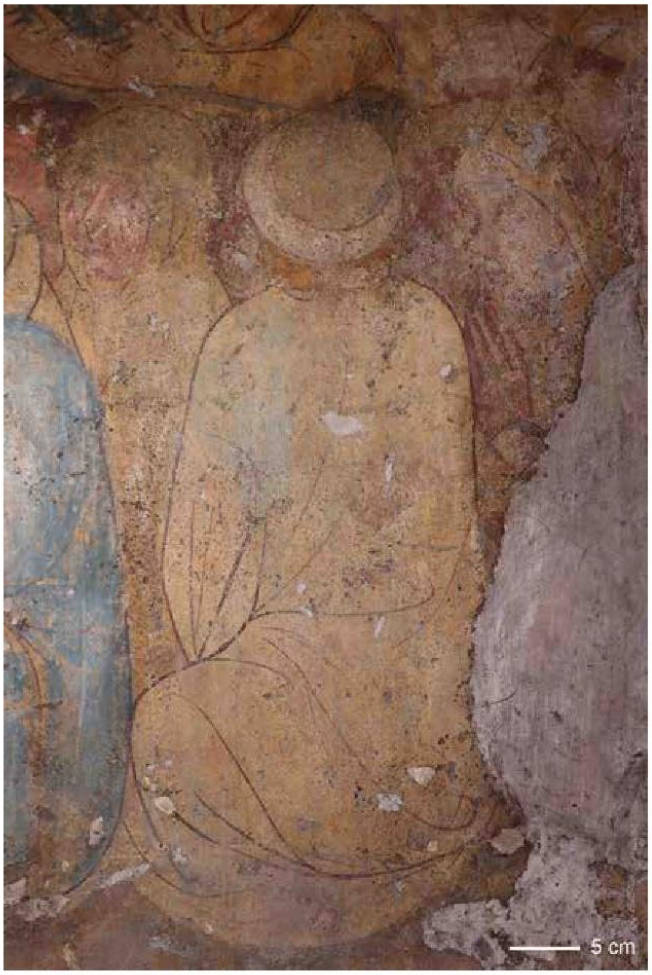
Figure 11: Excerpt from the Catalogue of phenomena, part A - original, added and altered materials. © Daniela Jakubů, Jan Vojtěchovský, Katharina Schellbach, Radka Farská, Juliána Tkočová, Simona Kubasová.

B - Condition

Phenomenon: Exposed imprimatura and underdrawing

Number: B5
Code: 091
Location: North walk, bay 16 (16 + 17)
Mapping: No

Detail image, example A



Description

Throughout much of the cycle, the final paint layer has not survived, leaving the underlying layers (imprimatura, brush underdrawing) exposed. In example A, the paint layer is completely lost in certain areas of the drapery. In example B, the imprimatura and brush underdrawing have been exposed in areas of presumed shadows within the drapery.

Figure 12: Excerpt from the Catalogue of phenomena, part B - condition. © Daniela Jakubů, Jan Vojtěchovský, Katharina Schellbach, Radka Farská, Juliána Tkáčová, Simona Kubasová.

C - phenomena for ongoing monitoring and/or treatment

Phenomenon: White haze

Number: C8

Code: 030

Location: East walk, bay 25 (32)

Mapping: Yes

Detail image, example A

Description:

White haze is present in bays 9(9), 10(10), 16(16+17), and 25(32), appearing in two different forms. Example A represents irregular mapping over the exposed original surface across various paint layers. Example B is linked to specific paint layers, such as red draperies or flesh tones. This indicates that the haze is more likely a result of Raimund Ondráček's previous interventions than other causes. Brushstrokes are visible within this whitish layer in certain locations.

Figure 13: Excerpt from the Catalogue of phenomena, part C - phenomena for ongoing monitoring and/or treatment. © Daniela Jakubů, Jan Vojtěchovský, Katharina Schellbach, Radka Farská, Juliána Tkáčová, Simona Kubasová.

4.3 Mapping

The mapping (graphical documentation) focuses on selected phenomena from all three catalogue categories. Phenomena are summarised into two types of graphic documentation called *Painting Technique* (Figure 15) and *Condition* (Figure 16). The graphical mapping is added to the overview mosaiced images of each bay. The basis for the mapping is photogrammetric images at a resolution of one pixel representing 0,5 mm, converted into black and white images in Adobe Photoshop. The mapped area is selected, and the colour intensity is reduced in the surrounding parts. The mapped area represents a conserved area. This means an area treated by conservator-restorers in the past and future should only be treated by graduated and licensed (in the Czech Republic) conservator-restorers. This area covers the preserved areas of the original painting, including the fills that are present in the area of the painting or the immediate surroundings. Parts of historical plaster without painting below the scenes (bay 2(2), 3(3), 8(8), 14(14), 15(15), 26(33)) are also included in the conserved area. Together, these representative areas are the basis for calculating and quantifying the individual phenomena mapped (Figure 14). In the conserved area are not included stone elements as the wall ribs and door and window linings, although carrying the original polychromies. Recent fills in the lower parts of the walls are not part of the conserved area. The modified photograph is then rectified using the graphical documentation software *Metigo Map 4.0*.

The mapping sheet is set for the A3 format for bays 1(1)-15(15) and 19(22)-26(33) and A2 format for the larger bays of the north wall 16(16+17), 17(18+19) and 18(20+21).

Bay number	Conserved area [m2]	Light coloured fills (big fills) [m2]	All fills [m2]	Historical plaster without paintings [m2]	Preserved (presented) paintings [m2]	Preserved (presented paintings [%]	Average of preserved paintings in the individual wings
1(1)	9,29		5,359	0,225	3,706	40%	
2(2)	13,194			6,816	6,378	48%	
3(3)	11,85	3,491		1,62	6,739	57%	
4(4)	12,905	1,259		0	11,646	90%	
5(5)	14,708		2,367	0	12,341	84%	
6(6)	14,915		3,676	0	11,239	75%	
7(7)	16,59		2,178	0	14,412	87%	69%
8(8)	10,347	3,818		0,26	6,269	61%	
9(9)	12,033	0,606		0	11,427	95%	
10(10)	12,72		1,738	0	10,982	86%	
11(11)	14,391	3,406		0	10,985	76%	
12(12)	14,414	3,675		0	10,739	75%	
13(13)	14,385	1,862		0	12,523	87%	
14(14)	14,448	2,746		1,12	10,582	73%	79%
15(15)	12,147	3,502		1,68	6,965	57%	
16(16+17)	28,84		3,776	0	25,064	87%	
17(18+19)	23,089	1,261		0	21,828	95%	
18(20+21)	27,116	2,768		0	24,348	90%	
19(22)	10,013	3,744		0	6,269	63%	78%
20(23)	8,259	3,447		0	4,812	58%	
21(24)	12,072	11,966		0	0,106	1%	
22(25)	12,308	4,533		0	7,775	63%	
23(26)	11,881	9,205		0	2,676	23%	
24(31)	13,533	2,818		0	10,715	79%	
25(32)	11,798		1,306	0	10,492	89%	
26(33)	14,752	3,033		1,48	10,239	69%	55%
Total:	371,998	67,14	20,4	13,201	271,257	73%	

Historical surfaces (plaster+paintings)... 284,5
Historical surface covered with wash... 4,405
Historical surfaces total... 288,9

Figure 14: Table summarising the state of preservation of the paintings, based on graphic mappings. ©Daniela Jakubů

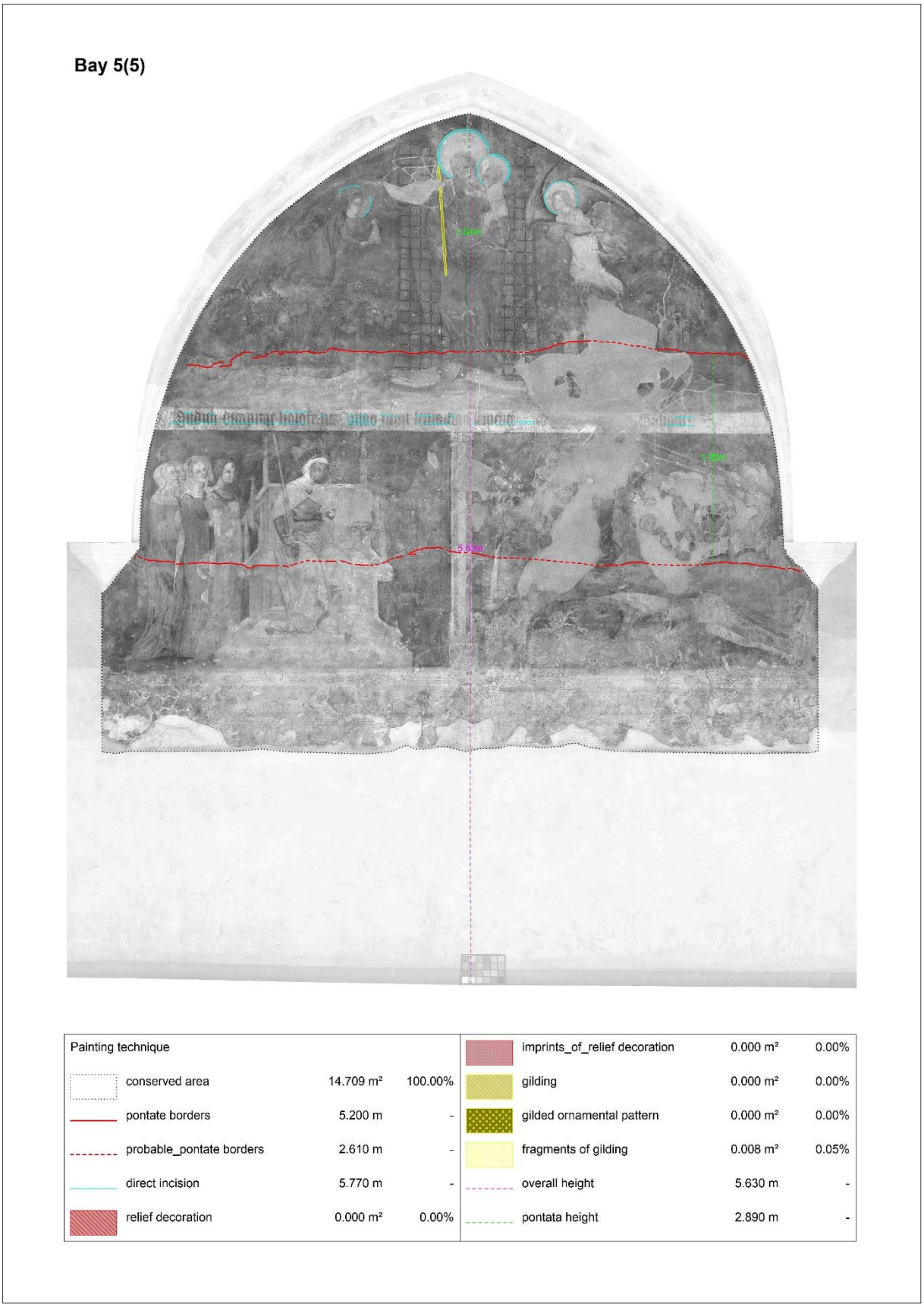


Figure 15: Example of the painting technique mapping, bay 5(5). ©Timea Töröková, Daniela Jakubů; photogrammetric image basis: © Jiří Vidman, Pavel Hlavenka.

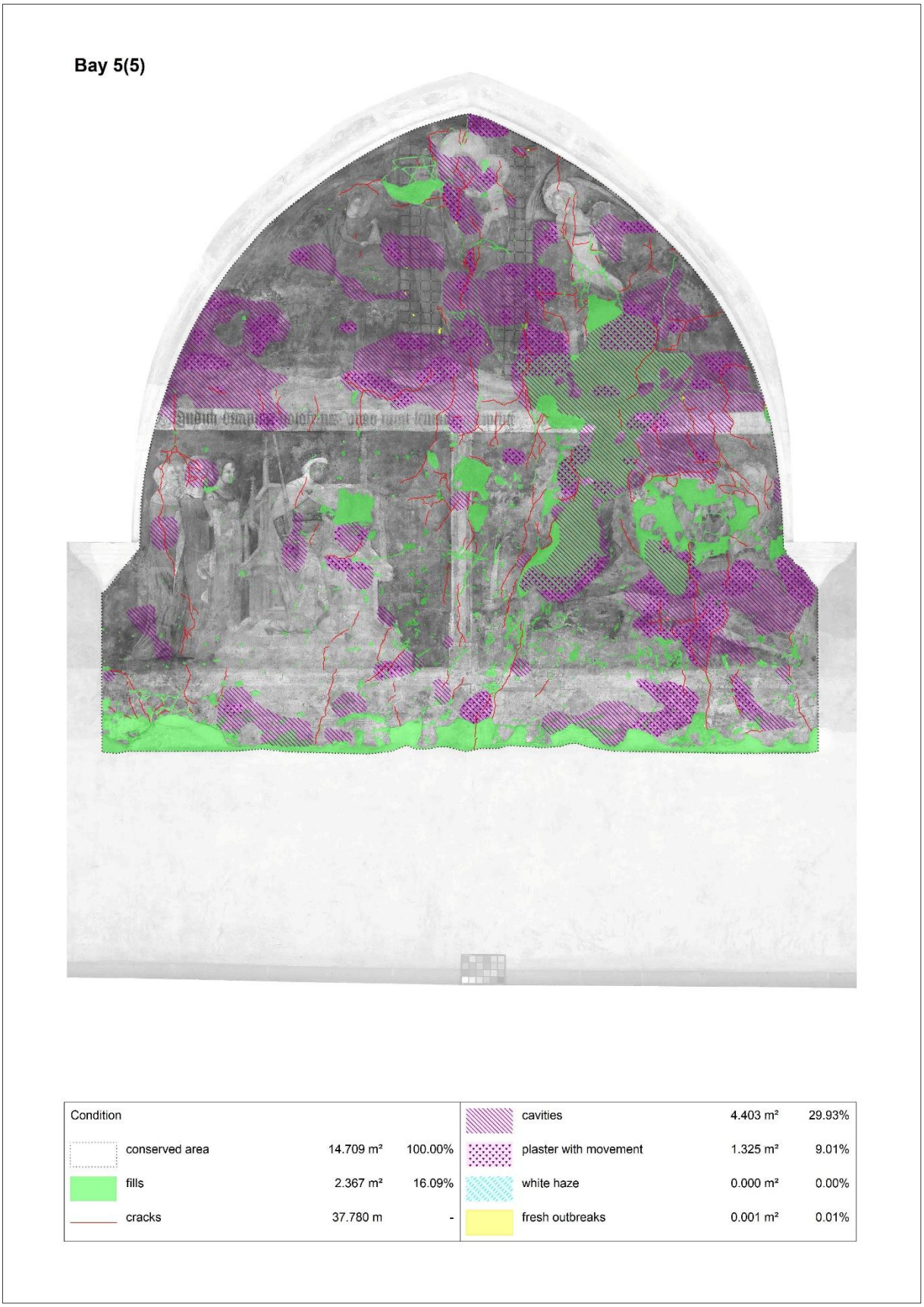


Figure 16: Example of the condition mapping, bay 5(5). ©Timea Töröková, Daniela Jakubů; photogrammetric image basis: © Jiří Vidman, Pavel Hlavenka.

5 WP4: Investigation of selected areas using non-invasive imaging techniques

→ Corresponding chapters in the final report: Chapter 2.5 Investigation of Selected Areas Using Non-Invasive Imaging Techniques (WP4), Chapter 3.2 Painting Technique and Materials, Chapter 3.4 Application of the Phase One Rainbow System on Wall Paintings

5.1 UV luminescence photography

Ultraviolet-induced luminescence photography (Figure 17) for all 26 bays of the cloister was performed by the UPCE team in cooperation with PhDr. Martin Mádl, Ph.D. from the Institute of Art History of the CAS. The images of the individual bays were aligned with the photogrammetric images. To facilitate comparison, the individual fields were also stitched into composite views of the entire cloister walk.

Figure 17: UVL image of the west walk. © UPCE, Martin Mádl, Jiří Vidman, Pavel Hlavenka.

of selected bays: on bays 5, 6, 10, 16 (16 + 17), 25 (32) completely and on selected parts of bays 1 (1), 2 (2) and 3 (3).

5.2 Set of so-called technical photography

Technical photography included sets of the following images (Figure 18): reflected visible photography (VIS), UV luminescence photography (UVL), reflected UV photography (UVR) and reflected IR photography (IRR). From the pictures taken, photogrammetric compositions of whole bays were created. On these compositions, false-colour reflected images (UVRFC, IRRFC) and false-colour UV luminescence images (UVLFC) were produced. The recording was performed using a full spectrum modified digital camera with external filters. Examined bays were 1 (1), 5 (5), 6 (6), 10 (10), 16 (16 + 17), 25 (32) and selected parts of bays 2 (2) and 3 (3).

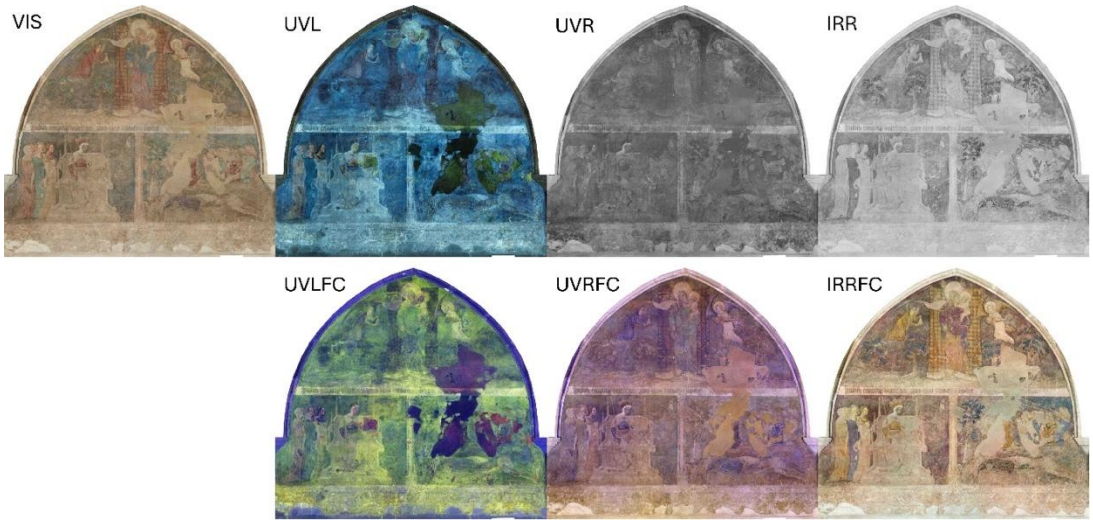


Figure 18: Technical photography of bay 5 (5). © UPCE, Jiří Vidman, Pavel Hlavenka.

5.3 IR Thermography

Infrared thermography was carried out by Marek Eisler and Jaroslav Valach, Ph.D., from the Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences (CAS). Rectified ortho-thermograms of all 26 bays and, ultimately, all four walks of the cloister were stitched from individual captures while testing various objective lenses (Figure 19, Figure 20).

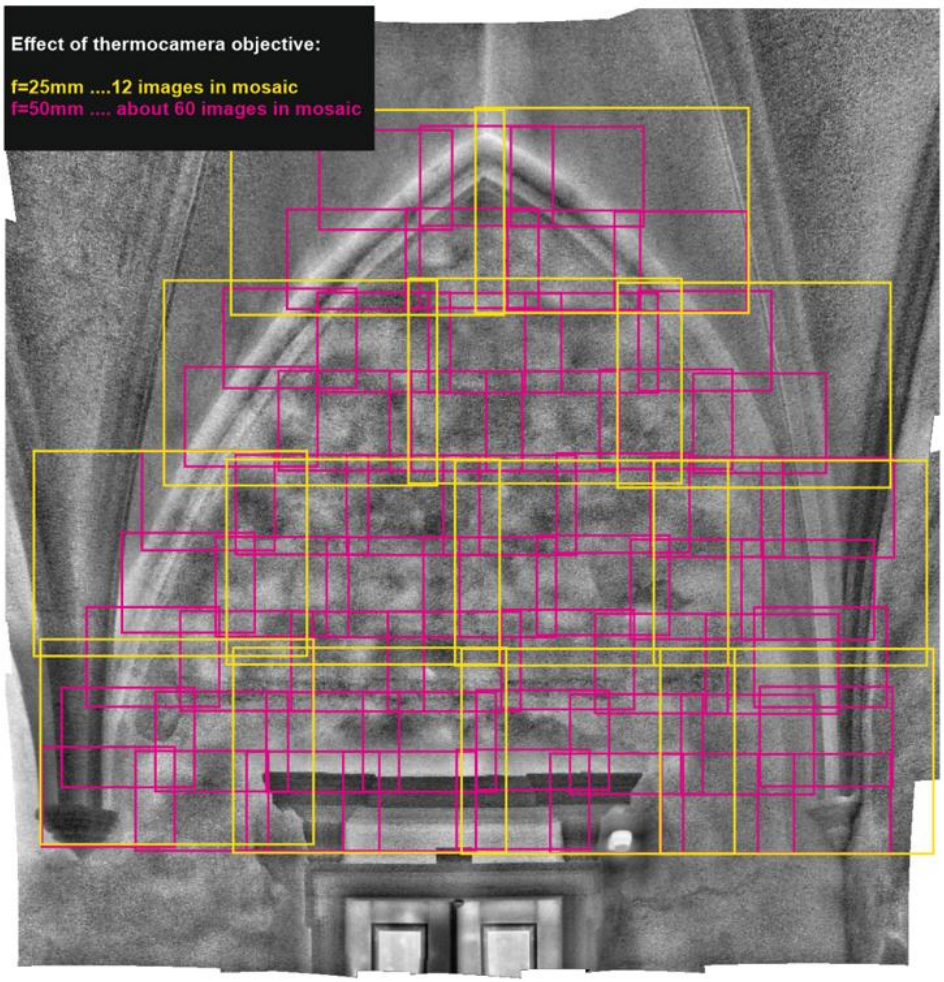


Figure 19: Process of capturing IR thermographic images, a difference in number of tiles necessary to cover one bay using objective lens with focal length of 25mm (yellow rectangles) and of 50mm (purple rectangles). ©: Marek Eisler, Jaroslav Valach.

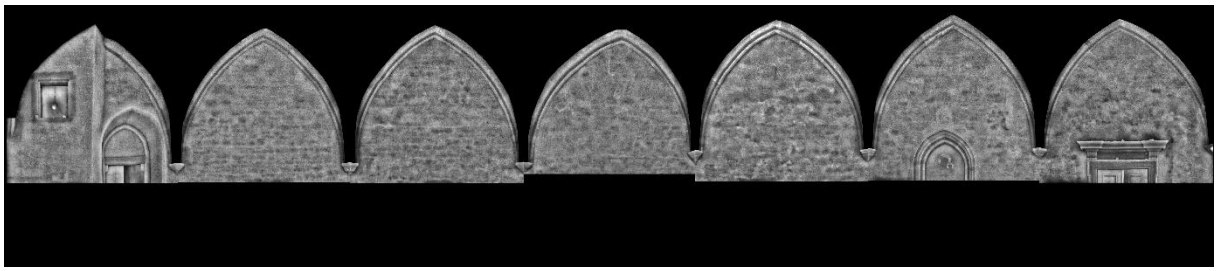


Figure 20: East walk of the cloister as rectified "ortho-thermogram". © Marek Eisler, Jaroslav Valach, Jiří Vidman, Pavel Hlavenka.

5.4 Multispectral imaging with the *Phase One* Rainbow System

During the campaign, the *Phase One* Rainbow Multispectral Imaging (MSI) Solution (hereafter referred to as the *Phase One* Rainbow System) was used to acquire large-area multiband and narrowband multispectral image data directly from the wall paintings in situ. Together with Annette T. Keller, an expert in multispectral imaging, the team from the ABK Stuttgart conducted a comprehensive, non-invasive material analysis of the wall surfaces. The multispectral images complemented the visual examination and technical photography, while also preparing the ground for further non-contact measurement methods by targeting suitable measurement points. The multispectral images focused on selected areas of the wall painting cycle, chosen for their state of preservation, restoration history, and suitability for further investigation. The areas examined included bays 3 (3), 5 (5), 6 (6), 10 (10), 16 (16+17) and 25 (32) (Figure 21).

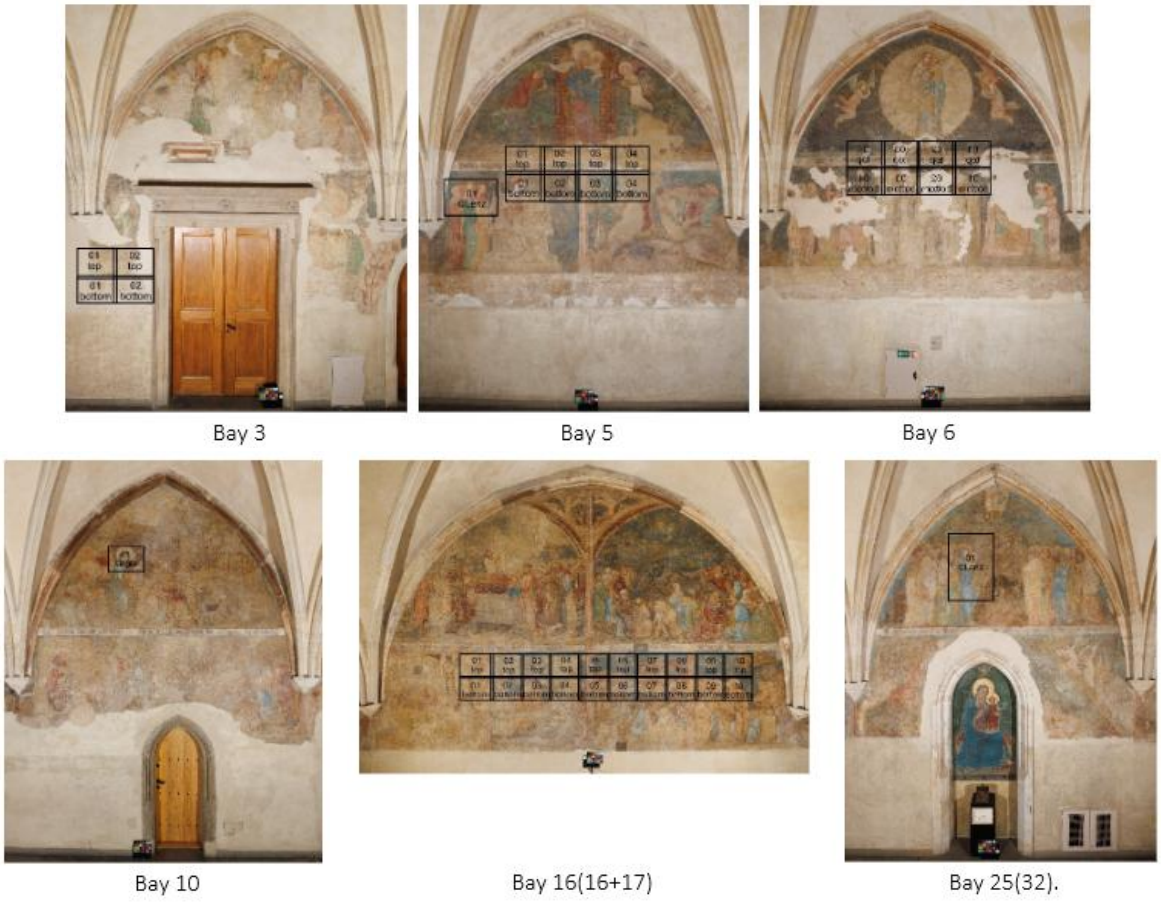


Figure 21: Showing the location of the recordings in the respective bays (2023 image basis ©Jan Vojtěchovský, 2026 image editing ©Katharina Schellbach).

The documentation included images in the visible, ultraviolet, and infrared spectral ranges. Both multiband and narrowband images were acquired and subsequently combined into spectral image stacks. Each stack consisted of eight multiband and sixteen narrowband images (Figure 22).

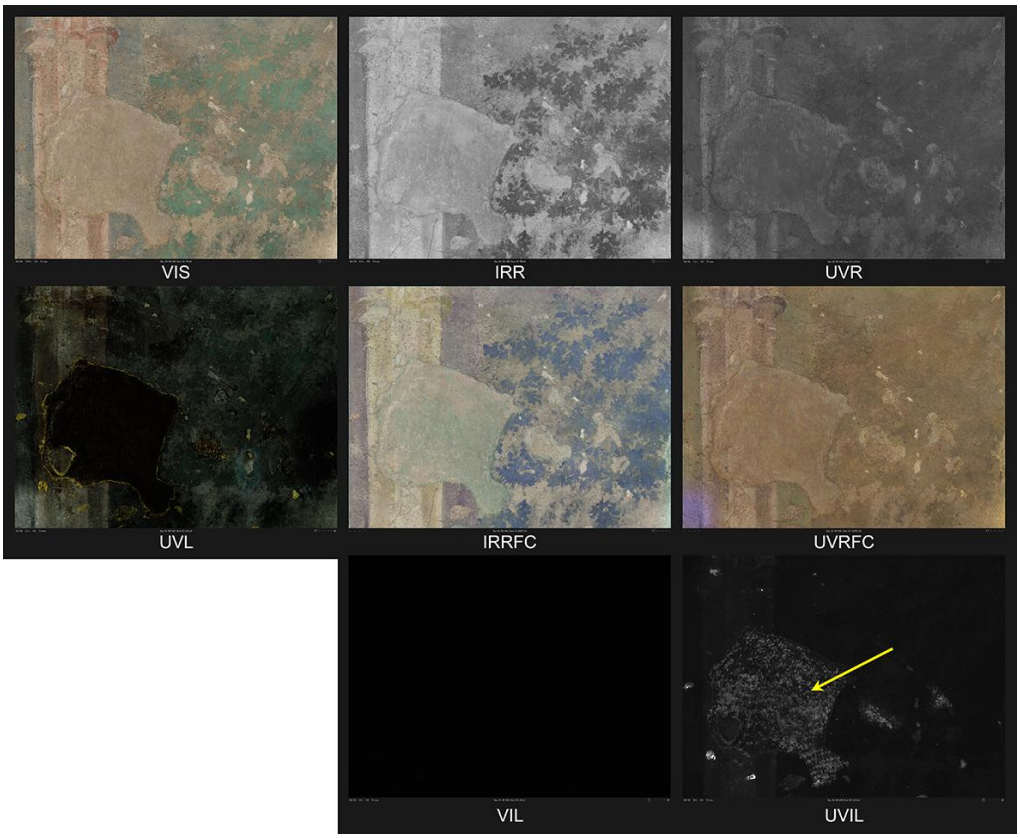


Figure 22: Software Capture One, montage of multiband images side by side of bay 5 (5) (2024 image basis ©Annette T. Keller, 2025 image editing ©Roland Lenz).

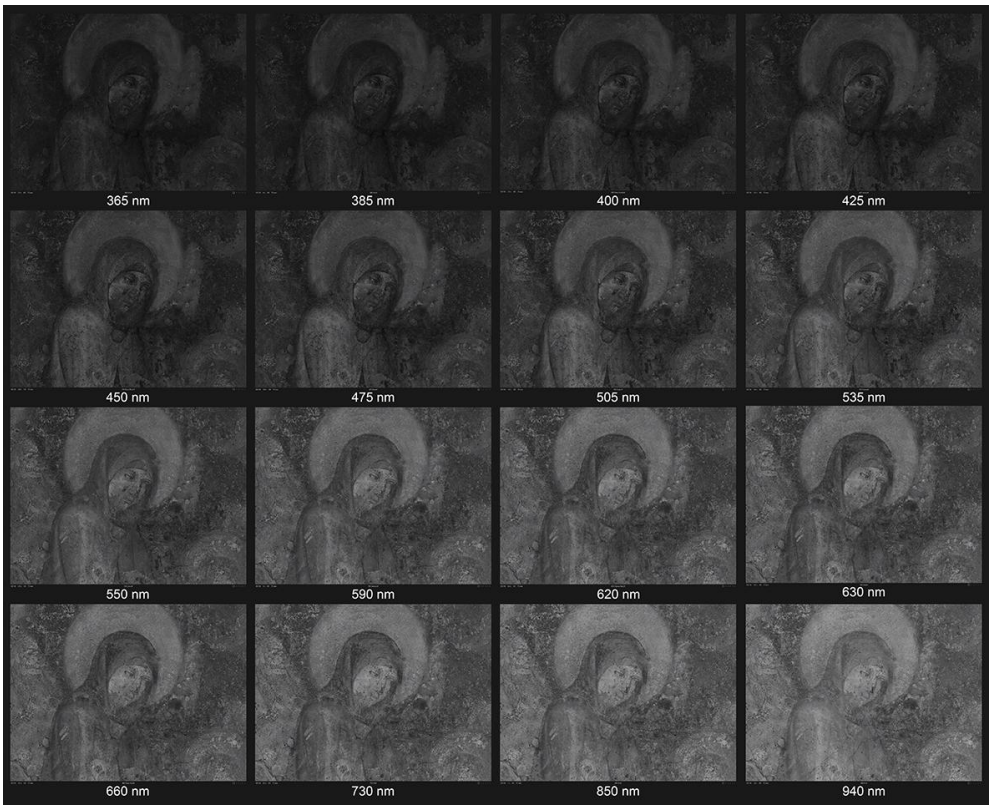


Figure 23: Software Capture One, montage of narrowband images side by side of bay 10 (10) (2024 image basis ©Annette T. Keller, 2025 image editing ©Roland Lenz).

The Rainbow System consists of a modified camera unit with multiband and narrowband illumination, various filter combinations, and an automated exposure control system. A rollable tripod design was developed specifically for this project to enable mobile movement along the scaffolding (Figure 24, Figure 25).

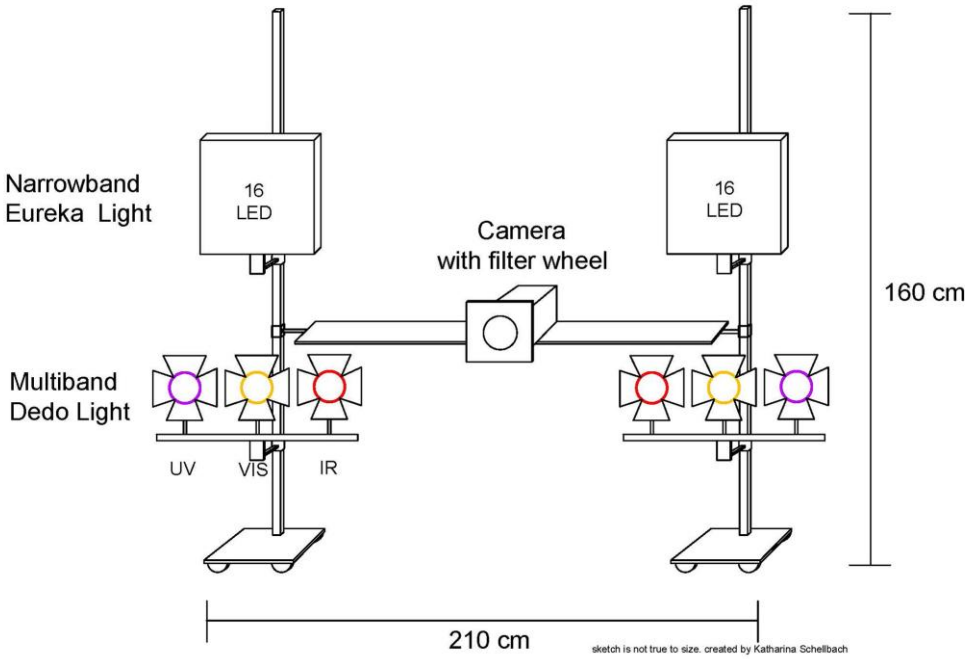


Figure 24: Sketch of the Rainbow System, not true to size ©Katharina Schellbach.

Figure 25: The Rainbow System from the back on scaffold ©David Svoboda.

5.5 Analysis of Spectral Images

The analysis of spectral images required suitable research questions and an understanding of processes such as reflection, absorption, transmission, and luminescence. Comparing the images made it possible to identify areas with similar or different spectral behaviour.

The focus was on assessing the homogeneity of colour areas, distinguishing pigments, and detecting later interventions such as fillings, overpainting, and retouching. Different restoration or working phases could also be recognized, supporting the selection of areas for further non-destructive material analysis. The multiband images were evaluated by a conservator-restorer using image-editing software, Rainbow-MSI, and DStretch®.

5.5.1 Analysis Using Image Processing Software

The initial analysis compared all images (VIS, UVR, IRR, UVIL, VIL, UVL; IRRFC, UVRFC) directly on screen. Areas with consistent spectral behaviour across all images were considered identical, while deviations indicated different materials or alterations.

For example, in bay 5, green leaves appear homogeneous in VIS, IRR, and IRRFC. In contrast, UVIL reveals IR luminescence under UV excitation, showing a uniform brushstroke pattern not visible in VIS. Such luminescence occurs only weakly in the Emmaus Abbey wall paintings and is mainly associated with retouching.

5.5.2 The Rainbow MSI Software

The Rainbow MSI software enables the analysis of multi- and narrowband images captured with the Rainbow system. It provides tools such as Spectral Readout, K-means clustering, PCA, and ICA, which were evaluated in this project for selecting measurement points for further non-destructive investigations.

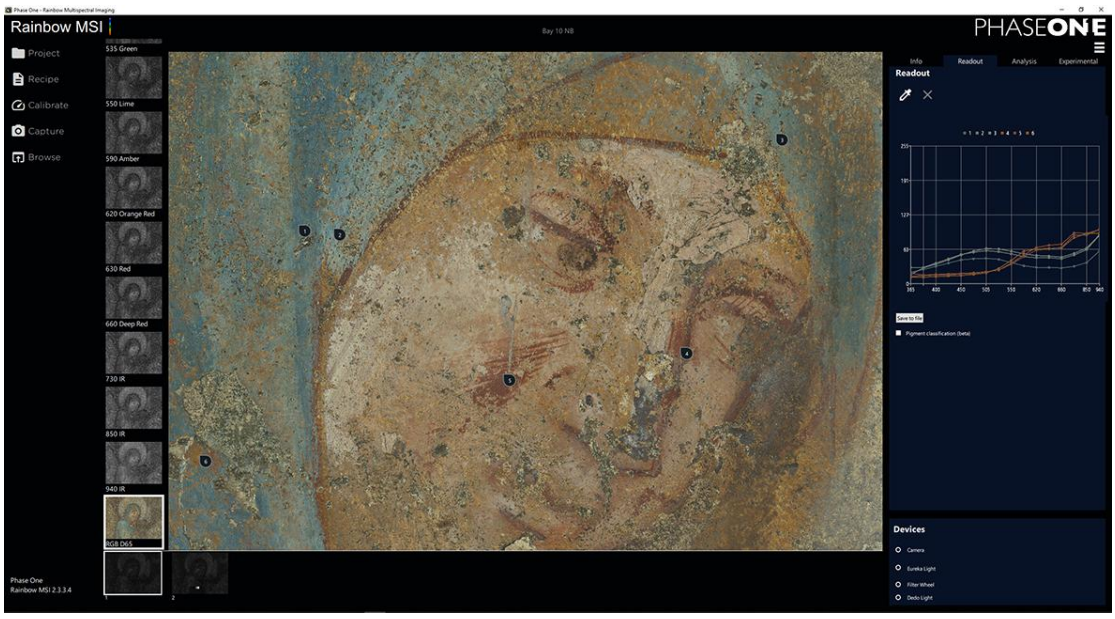


Figure 26: Software Rainbow MSI, Spectra Readout in the face of Mary in bay 10 (10), blue and red colour ranges (2024, image basis ©Annette T. Keller).

The Spectral Readout Tool generates reflectance curves from sixteen narrowband images covering approximately 365–940 nm. Because the images are precisely aligned, spectral information from the UV, visible, and near-infrared regions can be compared, revealing differences between visually similar areas that are not detectable in the visible spectrum alone (Figure 26).

For image stacks, the software provides PCA, ICA, and K-means clustering to group areas with similar spectral behaviour and highlight surface differences, also used in palimpsest analysis.
In this project, K-means clustering produced particularly useful results for both multiband and narrowband data by forming clusters that reveal material differences and changes. While both data types showed many similarities, multiband stacks were often more informative due to additional luminescence information, especially UVL images, which improved differentiation of specific areas (Figure 27, Figure 28).

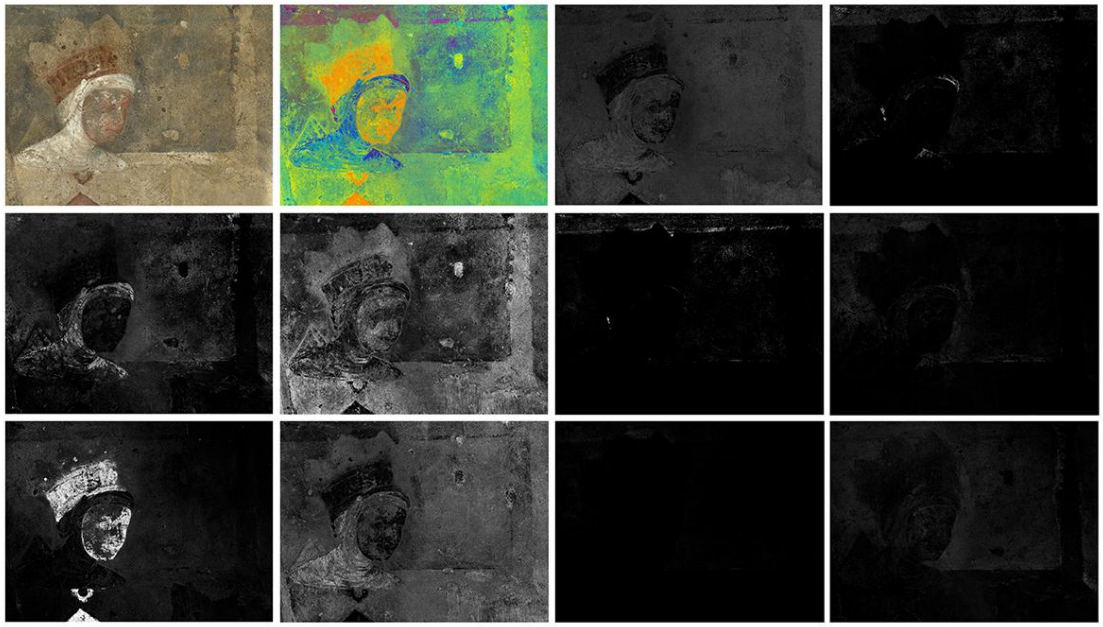


Figure 27: Software Rainbow MSI, Clustering (K-means) with Narrowband in bay 5 (5), Standard Normal Variate (SNV), 400-660 nm (2024 image basis ©Annette T. Keller, 2025 image editing ©Roland Lenz).

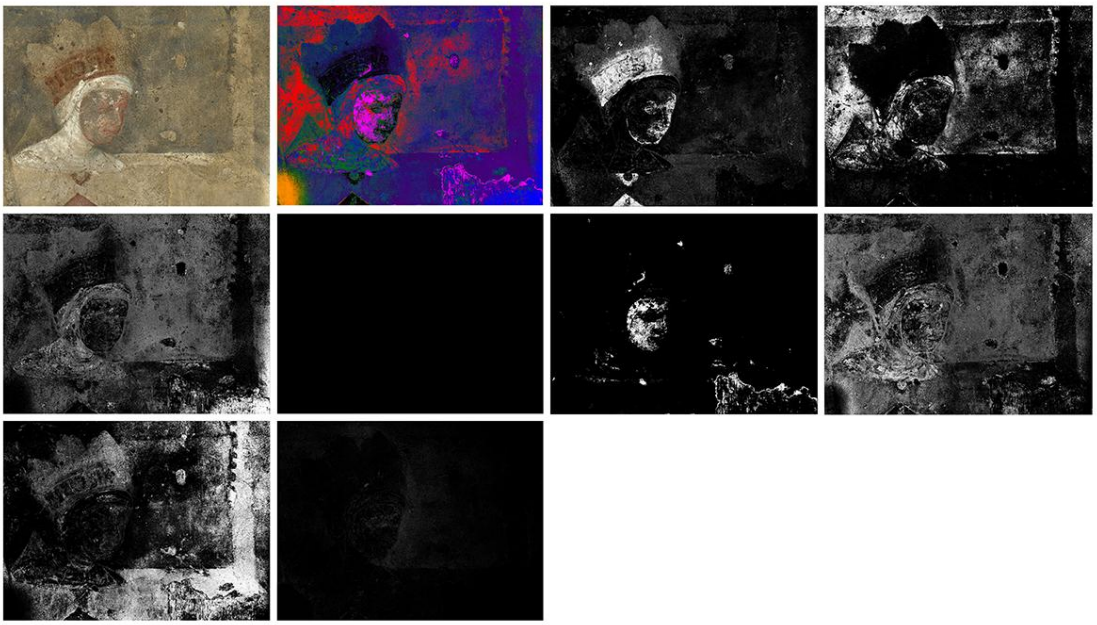


Figure 28: Software Rainbow MSI, Clustering (K-means) with Multiband in bay 5 (5), Standard Normal Variate (SNV), without IR-L and False Colour (2024 image basis ©Annette T. Keller, 2025 image editing ©Roland Lenz).

5.5.3 *DStretch®* Software

DStretch® was developed by Jon Harman to enhance the visibility of faint structures in images and is available as an ImageJ plugin and app. By modifying colour balance, increasing contrast, and applying colour-space transformations, it produces false-colour images in which subtle features become more visible. Originally developed for rock art research, it is now widely used in archaeology, art history, and conservation.

Only RGB-based colour images can be processed; therefore, narrow-band reflection images and UV/IR multiband data are unsuitable. In contrast, IRFC and UVFC false-colour images can be used. In this project, DStretch® proved especially useful in combination with UVL images. Processing in different colour spaces enhanced barely visible details and helped distinguish materials and intervention traces such as retouching or coatings through distinct colour contrasts. Figure 29 presents the VIS, UVRFC, IRRFC, and UVL images together with selected DStretch® results.

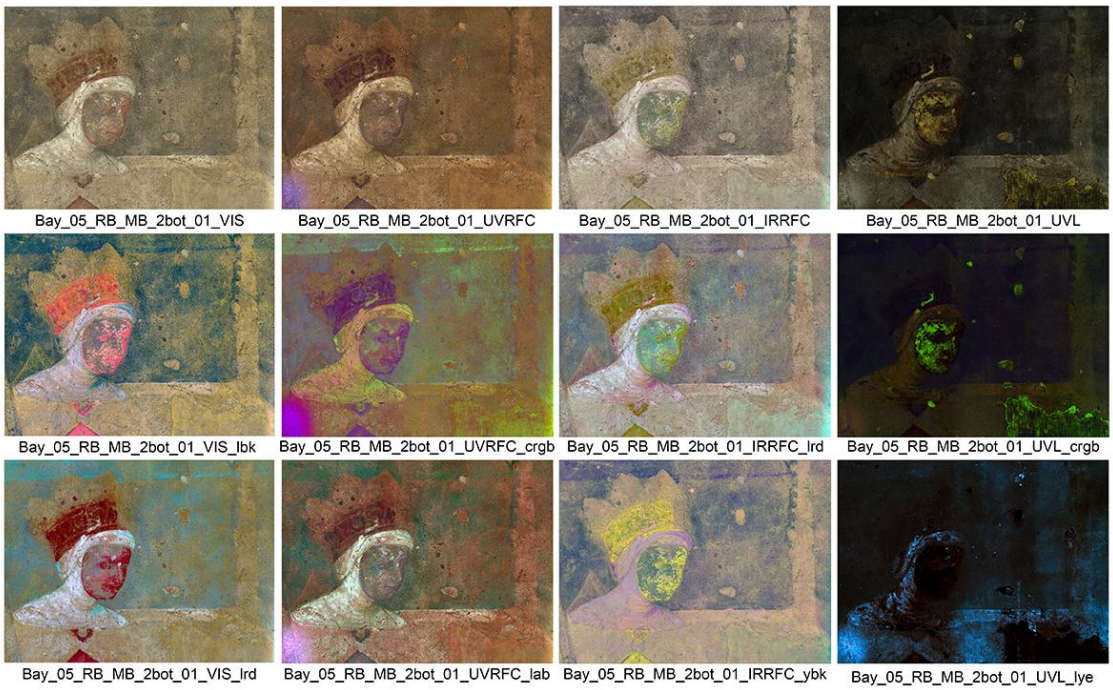


Figure 29: Examples of the application of DStrech® in bay 5(5), VIS-, UVFC-, IRRFC- and UVL-image (2024 image basis ©Annette T. Keller, 2025 image editing ©Roland Lenz).

5.6 Strengths and Weaknesses of Image Analysis Methods

The methods used to analyse narrowband and multiband images differ in their applicability and limitations. Direct image comparison in standard software enables flexible visual assessment through adjustments of brightness, contrast, and colour, but reproducibility is limited without reference targets. Rainbow MSI provides specialized tools such as Spectral Readout and K-Means clustering. Spectral Readout generates spectral curves from narrowband data, while K-Means clustering highlights spectral similarities in narrowband and multiband image stacks. However, some data types, including false-colour and IR luminescence images, cannot be analysed.

DStretch® enhances subtle features through colour-space transformations and offers highly reproducible results, but it is restricted to RGB colour images and cannot process grayscale data such as VIL or UVIL.

Overall, all methods are useful for identifying spectral differences, although they vary in precision and data coverage. As neither multiband nor narrowband images provide true spectral measurements, material identification requires complementary hyperspectral or mobile analytical techniques.
Within the project, the combination of the as mentioned above methods made it possible to identify spectral similarities and differences in a highly targeted manner, thereby identifying promising measurement points and areas for the selective, non-invasive methods.

5.7 Mounting of the recordings

The following figures show examples of the mounted spectral images from bay 5 (5) (Figure 30).

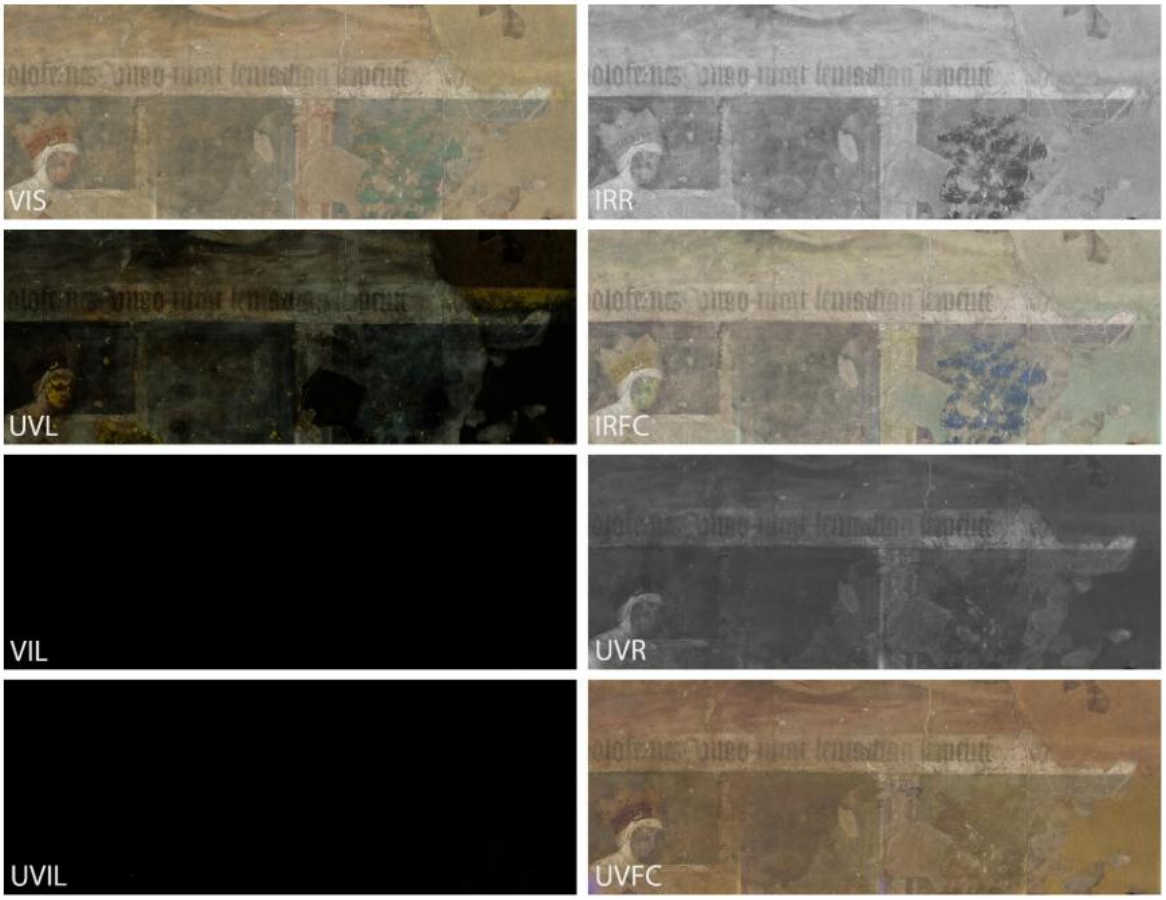


Figure 30: Mounting of the recordings from bay 5 (5) (2024 image basis ©Annette T. Keller, 2025 mounting ©Jiří Vidman).

6 WP5: Investigation of Selected Areas Using Non-Invasive Analytical Methods

→ Corresponding chapters in the final report: Chapter 2.6 Investigation of Selected Areas Using Non-Invasive Analytical Methods (WP5), Chapter 3.2 Painting Technique and Materials, Chapter 3.3 Current Condition and Deterioration Phenomena

6.1 Non-Destructive Analysis of Wall Paintings

WP5 was led by ABK Stuttgart with the participation of UPCE FR. On behalf of UPCE FR, Petra Lesniaková set up comprehensive pXRF measurements as part of a large-scale measurement campaign right at the start of the project. These measurements, along with the analysed spectral images from the WP4, formed the basis for the follow-up spectroscopic measurements conducted by ABK Stuttgart. Judit Zöldföldi from MPA Stuttgart was brought into the project to assist with the ABK Stuttgart's measurements. ABK Stuttgart carried out two large-scale measurement campaigns lasting several days. The first campaign took place in Bays 1 (1), 3 (3), 5 (5), 6 (6), 10 (10), 16 (16+17), and 25 (32).

For the second campaign, the insiTUMlab at the Technical University of Munich was also brought on board, which led to an expansion of the measurement methods and analytical equipment -- nevertheless, the expertise of the scientists from the Technical University of Munich, namely: Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann. This allowed the results of the first campaign to be verified and further analysed using complementary measurement methods.

The measurement sites were selected based on the results of the spectral images created and evaluated in WP5. From this, the most promising locations for spot analyses and imaging analyses were identified. Approximately 350 measurement points were recorded and precisely plotted on maps to ensure reproducibility in the future.

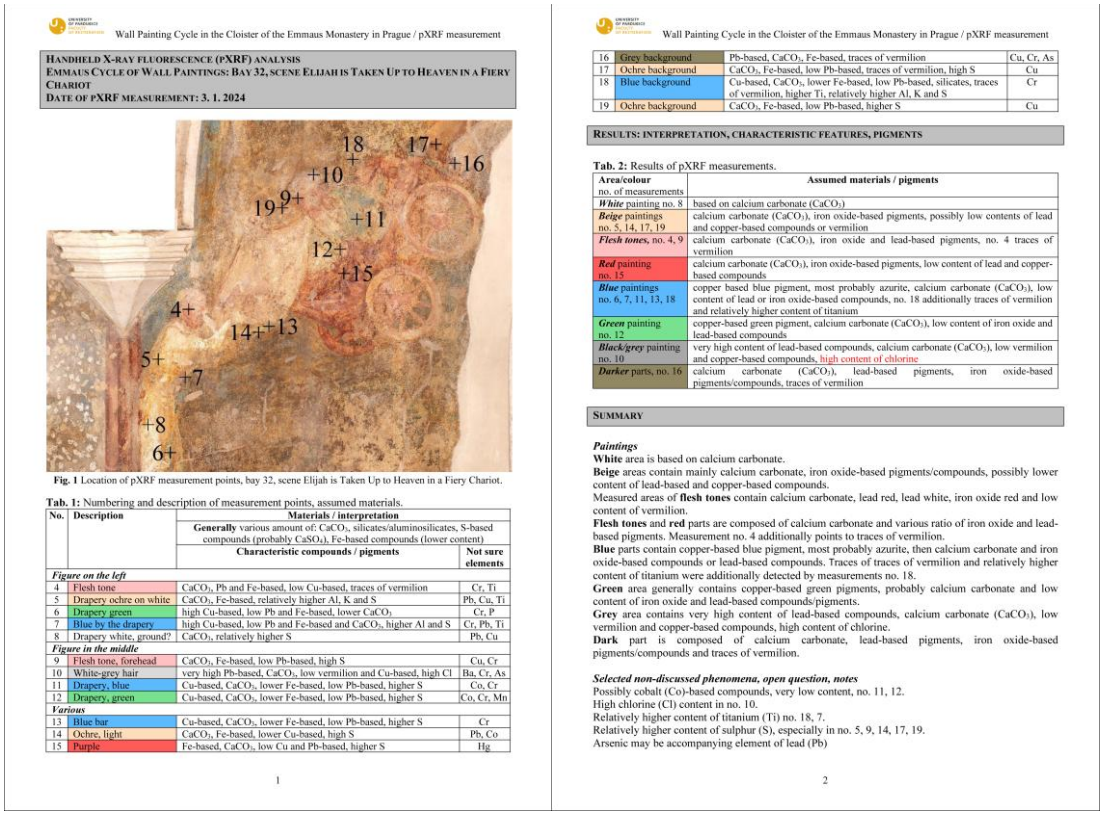
6.2 Broader screening by X-ray fluorescence spectroscopy (pXRF) by UPCE FR

Prior to and during further analytical investigations, a screening survey of the wall painting cycle was carried out using handheld X-ray fluorescence spectroscopy (pXRF). The measurements were performed by Petra Lesniaková from UPCE team using an Olympus Vanta VMR handheld X-ray fluorescence spectrometer. Approximately 1200 measurements were collected in Bays 1 (1), 3 (3), 5 (5), 6 (6), 7 (7), 10 (10), 16 (16+17), 23 (26), and 25 (32), covering a total of 22 scenes.

Figure 31: Example of the strategy of pXRF measurements on bay 25 (32). Photogrammetric image © Jiří Vidman, Pavel Hlavenka.

Figure 32: Example of the strategy of pXRF measurements on bay 6(6). Photogrammetric image © Jiří Vidman, Pavel Hlavenka.

The survey aimed to identify the principal pigments and gilding materials, evaluate their distribution within the broader number of scenes including scenes of main interest, and provide a systematic elemental dataset supporting the interpretation of complementary invasive and non-invasive analyses. An example of the measurement strategy and evaluation shows (Figure 31, Figure 32).



Wall Painting Cycle in the Cloister of the Emmaus Monastery in Prague / pXRF measurement

HANDHELD X-RAY FLUORESCENCE (PXRF) ANALYSIS
EMMAUS CYCLE OF WALL PAINTINGS: BAY 32, SCENE ELIJAH IS TAKEN UP TO HEAVEN IN A FIERY CHARIOT
DATE OF PXRF MEASUREMENT: 3. 1. 2024

Fig. 1 Location of pXRF measurement points, bay 32, scene Elijah is Taken Up to Heaven in a Fiery Chariot.

Tab. 1: Numbering and description of measurement points, assumed materials.

No.	Description	Materials / interpretation	
		Generally various amount of: $CaCO_3$, silicates/aluminosilicates, S-based compounds (probably $CaSO_4$), Fe-based compounds (lower content)	
		Characteristic compounds / pigments	**Not sure elements**
Figure on the left			
4	Flesh tone	$CaCO_3$, Pb and Fe-based, low Cu-based, traces of vermilion	Cr, Ti
5	Drapery ochre on white	$CaCO_3$, Fe-based, relatively higher Al, K and S	Pb, Cu, Ti
6	Drapery green	high Cu-based, low Pb and Fe-based, lower $CaCO_3$	Cr, P
7	Blue by the drapery	high Cu-based, low Pb and Fe-based and $CaCO_3$, higher Al and S	Cr, Pb, Ti
8	Drapery white, ground?	$CaCO_3$, relatively higher S	Pb, Cu
Figure in the middle			
9	Flesh tone, forehead	$CaCO_3$, Fe-based, low Pb-based, high S	Cu, Cr
10	White-grey hair	very high Pb-based, $CaCO_3$, low vermilion and Cu-based, high Cl	Ba, Cr, As
11	Drapery, blue	Cu-based, $CaCO_3$, lower Fe-based, low Pb-based, higher S	Co, Cr
12	Drapery, green	Cu-based, $CaCO_3$, lower Fe-based, low Pb-based, higher S	Co, Cr, Mn
Various			
13	Blue bar	Cu-based, $CaCO_3$, lower Fe-based, low Pb-based, higher S	Cr
14	Ochre, light	$CaCO_3$, Fe-based, lower Cu-based, high S	Pb, Co
15	Purple	Fe-based, $CaCO_3$, low Cu and Pb-based, higher S	Hg

1

Wall Painting Cycle in the Cloister of the Emmaus Monastery in Prague / pXRF measurement

16	Grey background	Pb-based, $CaCO_3$, Fe-based, traces of vermilion	Cu, Cr, As
17	Ochre background	$CaCO_3$, Fe-based, low Pb-based, traces of vermilion, high S	Cu
18	Blue background	Cu-based, $CaCO_3$, lower Fe-based, low Pb-based, silicates, traces of vermilion, higher Ti, relatively higher Al, K and S	Cr
19	Ochre background	$CaCO_3$, Fe-based, low Pb-based, higher S	Cu

RESULTS: INTERPRETATION, CHARACTERISTIC FEATURES, PIGMENTS

Tab. 2: Results of pXRF measurements.

Area/colour no. of measurements	**Assumed materials / pigments**
White painting no. 8	based on calcium carbonate ($CaCO_3$)
Beige paintings no. 5, 14, 17, 19	calcium carbonate ($CaCO_3$), iron oxide-based pigments, possibly low contents of lead and copper-based compounds or vermilion
Flesh tones, no. 4, 9	calcium carbonate ($CaCO_3$), iron oxide and lead-based pigments, no. 4 traces of vermilion
Red painting no. 15	calcium carbonate ($CaCO_3$), iron oxide-based pigments, low content of lead and copper-based compounds
Blue paintings no. 6, 7, 11, 13, 18	copper based blue pigment, most probably azurite, calcium carbonate ($CaCO_3$), low content of lead or iron oxide-based compounds, no. 18 additionally traces of vermilion and relatively higher content of titanium
Green painting no. 12	copper-based green pigment, calcium carbonate ($CaCO_3$), low content of iron oxide and lead-based compounds
Black/grey painting no. 10	very high content of lead-based compounds, calcium carbonate ($CaCO_3$), low vermilion and copper-based compounds, high content of chlorine
Darker parts, no. 16	calcium carbonate ($CaCO_3$), lead-based pigments, iron oxide-based pigments/compounds, traces of vermilion

SUMMARY

Paintings
White area is based on calcium carbonate.
Beige areas contain mainly calcium carbonate, iron oxide-based pigments/compounds, possibly lower content of lead-based and copper-based compounds.
Measured areas of **flesh tones** contain calcium carbonate, lead red, lead white, iron oxide red and low content of vermilion.
Flesh tones and **red** parts are composed of calcium carbonate and various ratio of iron oxide and lead-based pigments. Measurement no. 4 additionally points to traces of vermilion.
Blue parts contain copper-based blue pigment, most probably azurite, then calcium carbonate and iron oxide-based compounds or lead-based compounds. Traces of traces of vermilion and relatively higher content of titanium were additionally detected by measurements no. 18.
Green area generally contains copper-based green pigments, probably calcium carbonate and low content of iron oxide and lead-based compounds/pigments.
Grey area contains very high content of lead-based compounds, calcium carbonate ($CaCO_3$), low vermilion and copper-based compounds, high content of chlorine.
Dark part is composed of calcium carbonate, lead-based pigments, iron oxide-based pigments/compounds and traces of vermilion.

Selected non-discussed phenomena, open question, notes
Possibly cobalt (Co)-based compounds, very low content, no. 11, 12.
High chlorine (Cl) content in no. 10.
Relatively higher content of titanium (Ti) no. 18, 7.
Relatively higher content of sulphur (S), especially in no. 5, 9, 14, 17, 19.
Arsenic may be accompanying element of lead (Pb)

2

Figure 33: Example of the pXRF data evaluation, bay 25 (32), scene Elijah is Taken Up to Heaven in a Fiery Chariot. Photogrammetric image © Jiří Vidman, Pavel Hlavenka. results© Petra Lesniaková.

6.3 Methods of the MPA Stuttgart (1st Campaign)

A multi-method, non-destructive analytical approach (Figure 34) was applied to investigate the material composition of historical wall paintings, focusing on the identification of pigments, binders, and inorganic additives.

Portable Raman spectroscopy (pRaman) (MIRA-XTR, Metrohm, 780 nm, 100mW) was used for the molecular characterization of pigments based on their specific vibrational signatures. This method enabled precise in situ identification of both natural and synthetic pigment phases, including complex mixtures and degradation products, without any sample preparation (Figure 35).

Portable Near-infrared spectroscopy (pNIR) was conducted with the Rocket spectrometer (ARCoptics) in the spectral range of 900–2500 nm. The technique provided complementary information on organic components such as protein- or oil-based binders, waxes, and coatings. NIR spectra were evaluated using a tailored reference database reflecting the substrate and material diversity of the investigated wall paintings. Its greater penetration depth also enabled insights into subsurface layers (Figure 36).

Portable X-ray fluorescence analysis (pXRF) using the Niton XL3t GOLDD+ was employed to determine the elemental composition of the painting layers. This data supported pigment identification (e.g., Pb, Fe, Cu, Hg, As) and helped distinguish original materials from later interventions or contamination.

The combination of pRaman, pNIR, and pXRF provided a powerful toolset for the comprehensive, layer-sensitive, and non-invasive characterisation of wall painting materials, supporting both conservation diagnostics and art-historical interpretation. At the same time, the findings raise further questions—regarding the origin, transformation, and interaction of materials—which will require additional investigation using advanced physicochemical methods.

Figure 34: Bay 5 (5) overview of the measurement points and the combination of measurement methods (red: pNIR; blue: pRaman; green: pXRF by J. Zöldföldi; yellow: pXRF by P. Lesniaková), (2023 image basis ©Jan Vojtěchovský, 2026 image editing ©Katharina Schellbach)

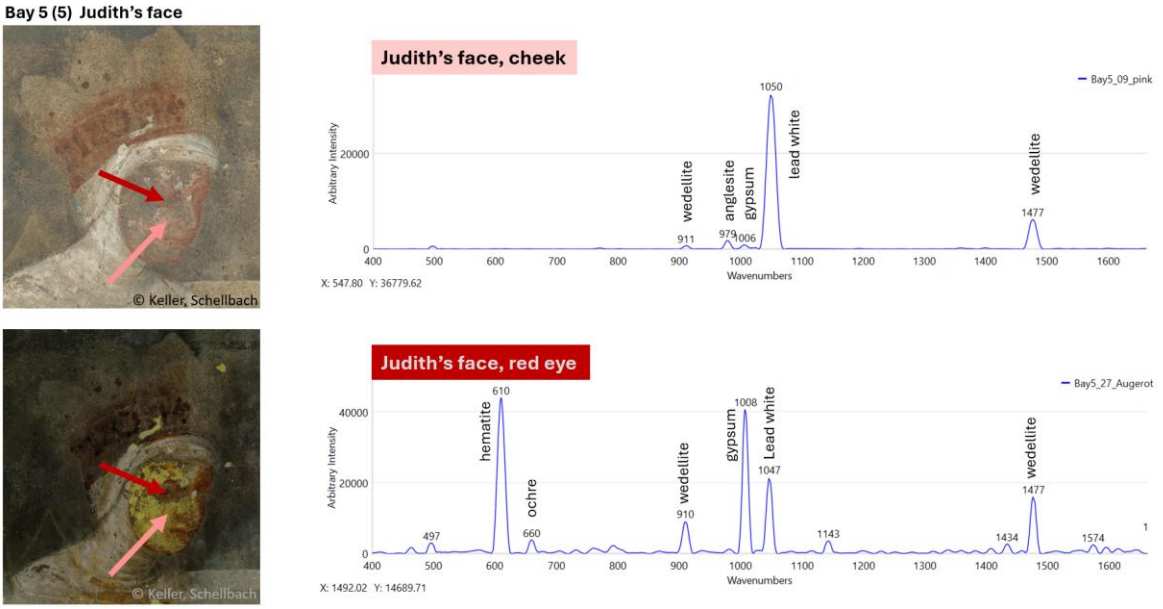


Figure 35: pRaman (MIRA) analysis in red parts of bay 5 (5) by Judit Zöldföldi. The analyses enabled the identification of hematite, ochre, lead white, wedellite and gypsum ©Judit Zöldföldi.

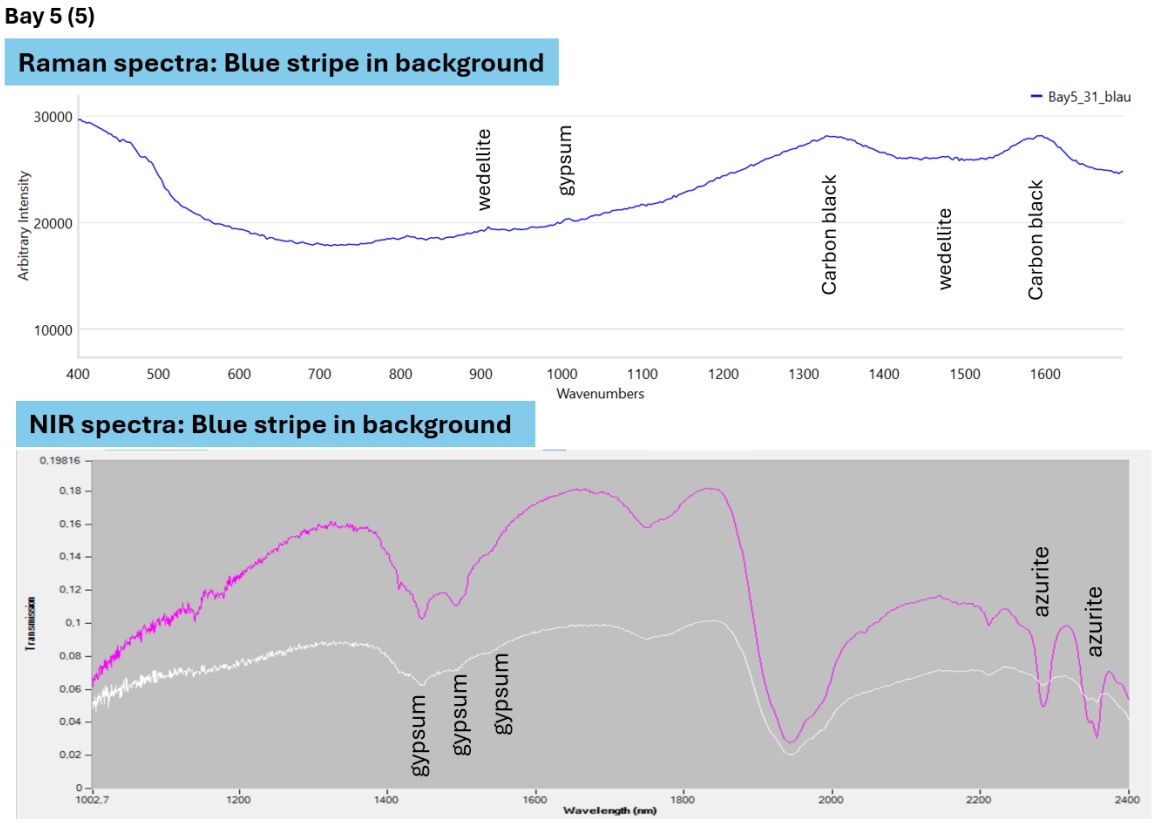


Figure 36: pRaman (MIRA) and pNIR analysis in the blue background of bay 5 (5) by Judit Zöldföldi. The analyses enabled the identification of azurite, carbon black, wedellite and gypsum ©Judit Zöldföldi.

6.4 Methods of the insiTUMlab (2nd Campaign)

The insiTUMlab investigations focused mainly on bay 5 (5) (Four Women, Judith's face and throne), bay 6 (6) (architectural decoration with a starry sky background), and bay 24 (31) (yellowish stains in an undecorated area), which were examined using a multimodal analytical approach. The complementary information provided by portable Raman spectroscopy, ER-FTIR spectroscopy, MA-XRF mapping, and hyperspectral imaging enabled the identification of pigments including hematite, red lead, vermilion, lead white, and azurite. Furthermore, a MA-XRF map of Judith's face revealed Zn–Ba-rich areas associated with a lacuna, suggesting the possible presence of lithopone (ZnS and $BaSO_4$), a material commonly used in restoration interventions (Figure 37). However, this interpretation requires further analytical confirmation.

Investigations under UV illumination enabled the differentiation of areas exhibiting distinct luminescence responses, indicating the possible presence of different organic compounds on the surface. Subsequent ER-FTIR analyses allowed the identification of PMMA and PVAc, previously documented as consolidation materials, in several locations. Hyperspectral imaging further enabled the mapping of PVAc in non-decorated areas of the wall surface.

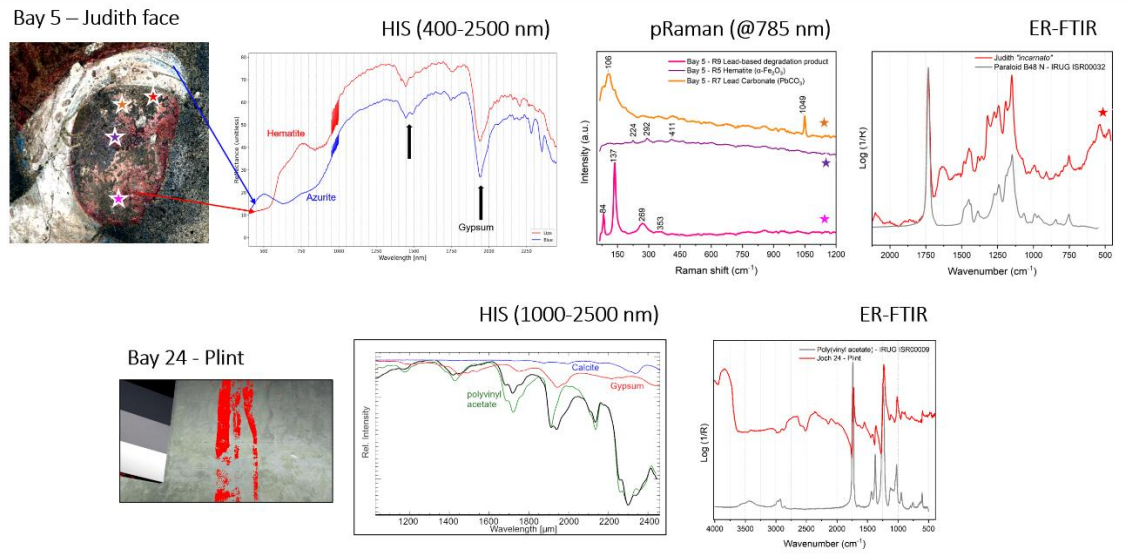


Figure 37: Example of the insiTUMlab contribution - Multimodal in situ investigations of bay 5 (5) (Judith's face) and bay 24 (31) (plinth) using HSI, pRaman (785 nm), ER-FTIR, and MA-XRF. The analyses enabled the identification of hematite, azurite, lead white, and a lead-based degradation product in bay 5 (5), as well as PMMA associated with past conservation treatments. In bay 24 (31), HSI and ER-FTIR revealed the presence and distribution of PVAc in undecorated areas together with gypsum and calcite. The colored markers indicate the locations of the point analyses. ©Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann.

Macro-X-Ray Fluorescence (MA-XRF) analysis was undertaken on selected points and areas. The measurements were acquired with an ELIO portable energy-dispersive X-ray fluorescence spectrometer (Bruker Nano GmbH, Berlin, Germany) with Rh-target microfocus 10-50 kV X-ray tube excitation and 17mm² Semiconductor Drift Detector (SDD) with CUBE technology detection. The system was equipped with an X/Y motor stage that permitted the scanning of 10 cm x 10 cm maximum areas with an analysis spot of circa 1mm. The spot measurements were performed at 50 kV tube voltage, 80 µA tube current, for 60s live time with a 1mm step size. Maps were acquired under the same tube voltage and current, with 2s per spot (dwell time). No Helium (He) and no filters were used for measurements.

Raman microspectroscopy (iRaman, 28 spots/measurements) was performed using a portable Raman microscope (B&WTek i-Raman® Plus, Metrohm Group, Herisau, Switzerland). Raman spectra were acquired using a portable B&WTek i-Raman® Plus spectrometer (Metrohm group, Herisau, Switzerland) equipped with a high-sensitivity TE-cooled CCD detector. The spectrometer is coupled to a 785 nm excitation laser (maximum output 455 mW) with a power adjustable by the operator. The measurements were performed over a spectral range of 65 to 3350 cm-1, with a resolution of 4.5 cm−1 at 912 nm. The laser power at the sample was kept as low as possible, at 1–10% of the maximum output for each measurement area, to avoid laser-induced modifications. Each spectrum was acquired with 10 accumulations to improve the signal-to-noise ratio. The instrument calibration was verified using a polystyrene standard provided by the manufacturer. Both excitation and collection signals are guided by optical fibres, which probe was used to carry out measurements.

External Reflectance Fourier-Transform infrared spectroscopy (ER-FTIR, 75 spots/measurements) A portable Alpha II spectrometer (Bruker Nano GmbH, Berlin, Germany) equipped with a CenterGlow™ source, a RockSolid™ interferometer (with gold mirrors), and a temperature-controlled DTGS detector was used to acquire the infrared spectra. Measurements were performed using a dedicated external reflection module (ER-FTIR) with specular optics (25°/25°) to collect the infrared radiation reflected from the surface. The external reflection module had an approximately 5 mm aperture, and for each

measurement point. The infrared spectra were collected in the spectral range of 7500-400 cm-1 with 64 co-added scans and a spectral resolution of 4 cm-1. An integrated USB high-resolution video camera provided a view of the analysed area, and a gold flat mirror supplied by the manufacturer was used for background correction.

Hyperspectral imaging (HIS, 4 areas) Measurements were performed using the HySpex VNIR-3000N and HySpex SWIR-384 sensor systems (Norsk Elektro Optikk AS, Skedsmokorset, Norway). The HySpex VNIR-3000N covers the visible and adjacent near infrared (NIR) spectral range of 400–1000 nm with 300 spectral channels, with a spectral sampling of 2 nm, 16° field of view (FOV) and a bit resolution of 12 bits. The HySpex SWIR-384 is instead designed to collect in the short-wave infrared (SWIR) range covering 960–2500 nm, with 288 spectral channels, 5.45 nm spectral sampling, an identical FOV of 16°, and a higher bit resolution of 16 bits. Both cameras were mounted on a motorized biaxial rotation stage, a mobile tripod, and an integrated illumination system for field use. The hyperspectral images were acquired at a distance of 1 m from the fragments to ensure the best trade-off between illumination intensity and field of view. The resulting spatial resolution was about 0.099 mm and 0.77 mm in the VNIR and SWIR, respectively. Data were acquired with HySpex Ground software. Zenith Lite™ Diffuse Reflectance Standards (Sphere Optics) with certified reflectance values of 90 %, 50 %, 20 %, and 5 % were included in each scan for radiometric calibration. The integration times were set to achieve approximately 80% saturation in the strongly reflecting areas of the fragments. For VNIR, these range from 69 to 75ms, and for SWIR, from 14 to 16 ms per frame. This resulted in acquisition times ranging from approximately 440 to 600 seconds. The data were corrected for dark current using the HySpex Rad software and calibrated using empirical line correction in Envi (nv5), fitting at-sensor reflectance for each calibration target using supplier-provided reference data. For material characterization, reflectance spectra were extracted from the image cube by calculating mean spectra across regions of interest with a minimum of 1000px for VNIR, and 100px for SWIR, due to different spatial resolutions (Figure 33, 34, 35).

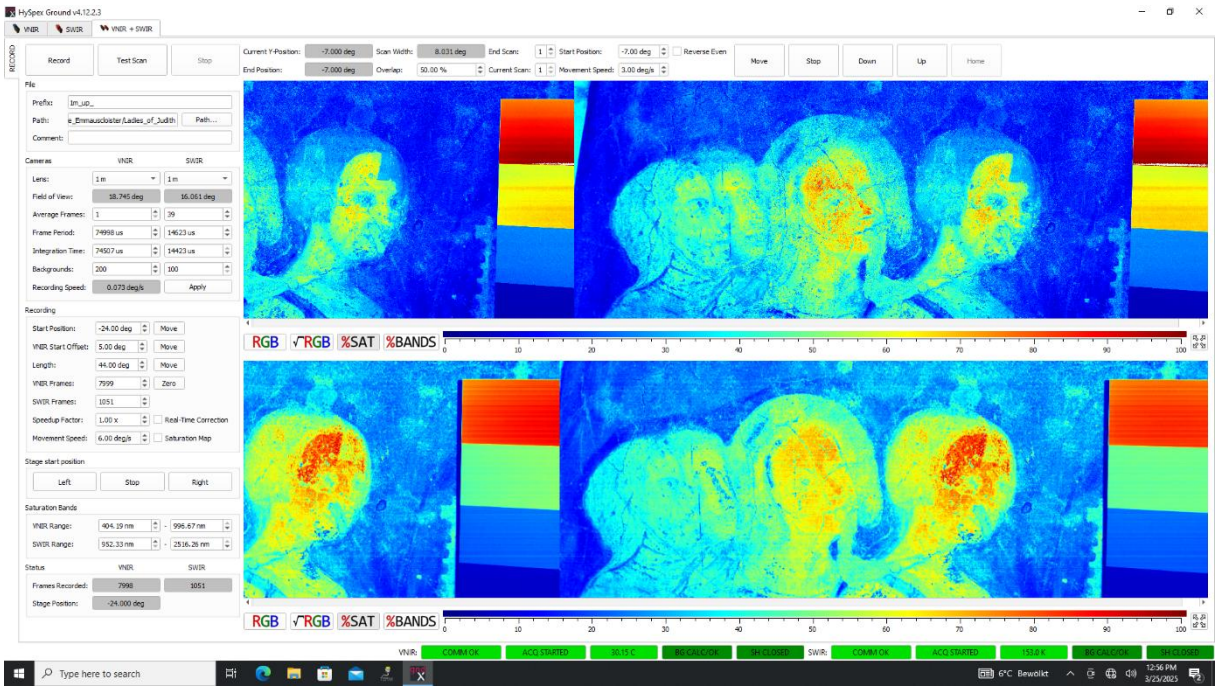


Figure 38: Hyperspectral imaging of bay 5 (5), Four Woman, ©Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann.

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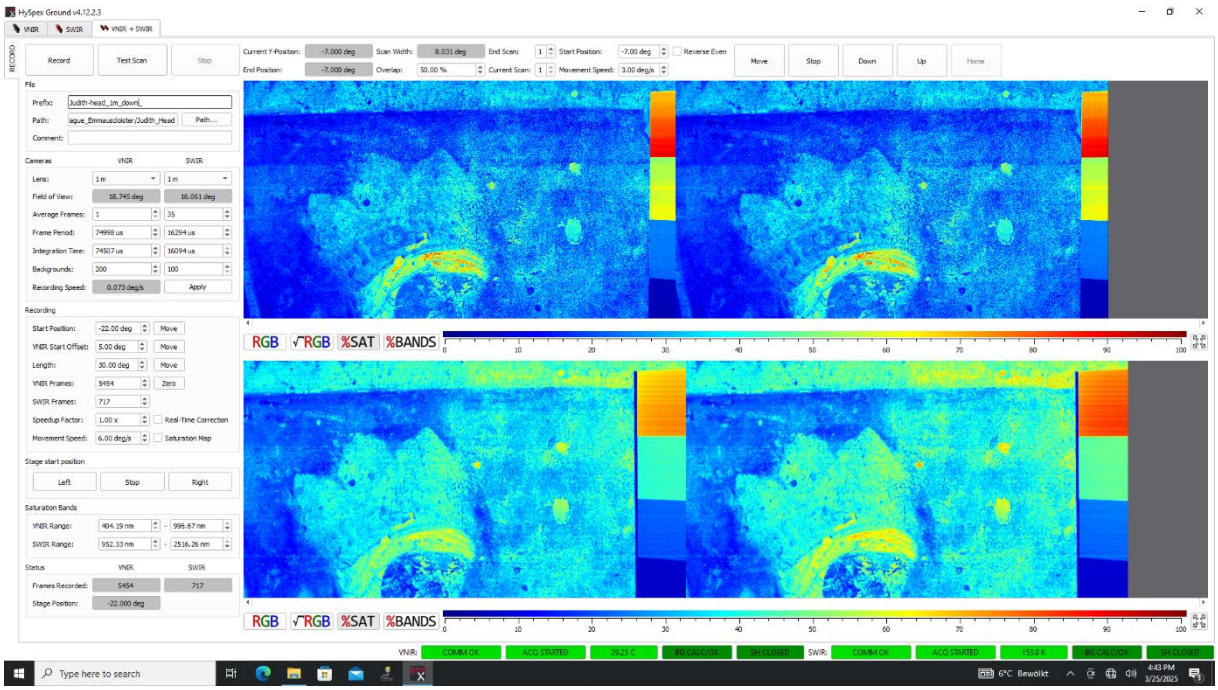


Figure 39: Hyperspectral imaging of bay 5 (5), face of Judith ©Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann

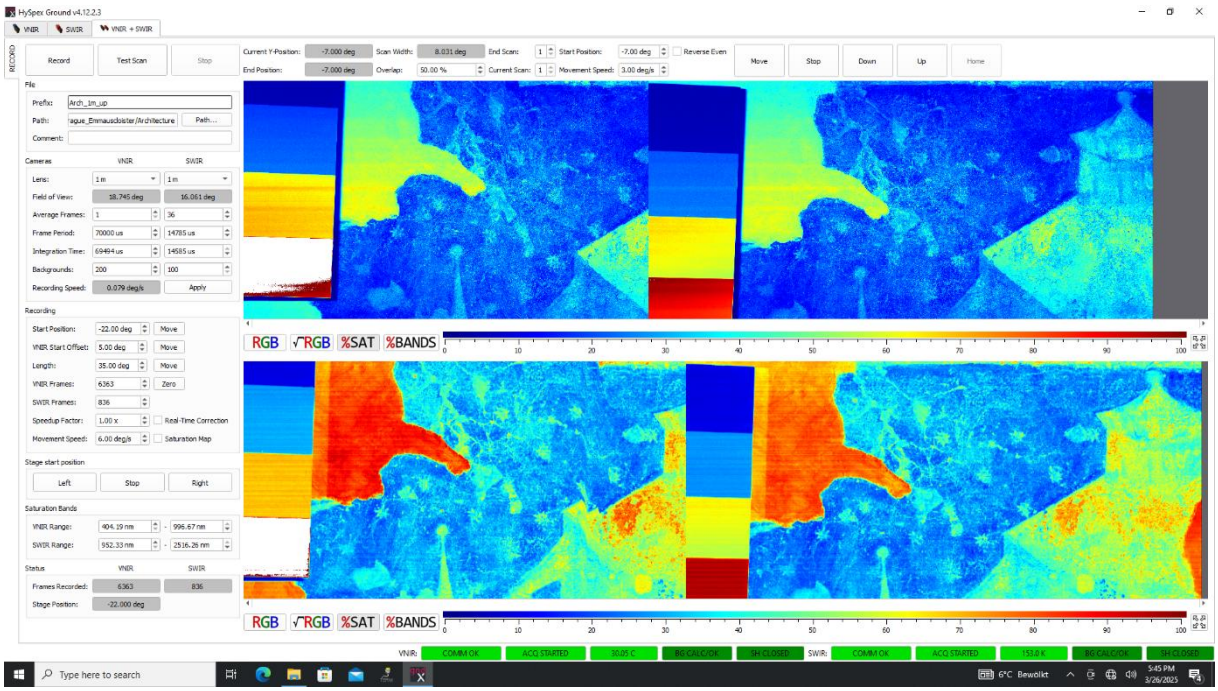


Figure 40: Hyperspectral imaging of bay 5 (5), architectural element with a starry sky background © Clarimma Sessa, Eva Mariasole Angelin, Simon Mindermann.

7 WP6: Environmental Assessment, Climate Monitoring and Implementation of the ABC Risk Assessment Method

→ Corresponding chapters in the final report: Chapter 2.7 Environmental Assessment, Climate Monitoring and Implementation of the ABC Risk Assessment Method (WP6), Chapter 3.5 Anthropogenic and Environmental Influences, Chapter 3.6 Implementation of the ABC Method

Work Package 6 investigated past, present, and potential future risks to the wall paintings arising from environmental conditions, the building fabric, and the use of the site. Understanding this wider context, including the building envelope, the surrounding environment, and the functional use of Emmaus Abbey, provided the basis for developing recommendations for future conservation planning and management.

All investigations within WP6 followed a fully non-invasive approach. The work was undertaken by the TH Köln team, with support from UPCE in facilitating site access and liaison with Emmaus Abbey. The investigations comprised:

- Archival research
- On-site inspections and interviews to identify potential risks in accordance with the Ten Agents of Deterioration
- A liquid moisture survey undertaken as part of the bachelor's thesis of Chari-Julian Tihanyi (2024)
- Research into historical sources of pollutants, including the former heating system
- Observation of insolation and measurement of surface temperatures
- A questionnaire on heating and ventilation practices
- Monitoring of ambient temperature, surface temperature, relative humidity, and calculated dew point
- Assessment of use-related factors
- Investigation of sulphur dioxide (SO_2) sources and evaluation of historical SO_2 data

Implementation of the ABC risk assessment method

7.1 Assessment of Use, User Groups and Movement Patterns

As part of WP6, the current and recent use of Emmaus Abbey was assessed in order to understand the functional and use-related context of the Emmaus Cycle. The assessment documented user groups, visitor numbers, access routes and typical movement patterns within the cloister, as these factors may influence environmental conditions, physical risks and future conservation planning. The following section summarises the data sources, forms of use, visitor development, movement patterns and implications for future planning.

7.1.1 Data Sources, Evaluation Method and Limitations

The assessment of patterns of use, user groups, and movement through the cloister was based on information provided by the Abbey administration together with the evaluation of available visitor and ticket data. These sources included annual ticket sales records from 2011 to 2024, detailed ticket sales data for 2024, logbooks and planning calendars documenting user groups, events, and access to different parts of the Abbey, on-site observations, and information on the typical routes used by different user groups within the cloister.

The data were evaluated descriptively. Annual ticket sales were analysed to assess long-term trends in paying visitors, while the 2024 dataset was examined according to user groups, monthly and seasonal distribution, weekdays, group size, ticket language, and larger group bookings. The typical routes of

different user groups were plotted on a floor plan to identify areas of more frequent use within the cloister.
The investigation has several limitations. Ticket data do not fully record the number of children participating in guided school or children's groups or the actual number of persons using family tickets. In addition, visitors attending church services and subsequently entering the cloister are not systematically recorded. The duration of visits and the precise movement patterns of individual users could therefore not be determined directly and were interpreted from the available data, on-site observations, and information provided by the Abbey administration. Consequently, the assessment provides a representative overview of patterns of use rather than a complete record of all movement within the cloister.

7.1.2 Current Use and Functional Context of Emmaus Abbey

Today, Emmaus Abbey is an active Benedictine abbey, run by five monks, and is also used for public, cultural and administrative purposes. The wall painting cycle is located in the cloister on the ground floor, which remains part of the everyday use of the Abbey. The Abbey church is adjacent to the cloister, and church visitors, including visitors to the Imperial Chapel, have access to parts of the cloister.
Offices and event rooms managed and used by the Abbey administration are located adjacent to the cloister on the ground floor. The first-floor cloister is used by the monastic community and is not open to the public. The rooms on the second and third floors are permanently rented out as practice rooms. Access for staff working there and for their clientele is possible via the side and main entrances, both of which lead through the cloister.
Events such as choir rehearsals, concerts, balls and conferences are regularly held in temporarily rented rooms on the ground floor, particularly in the Refectory. In addition, the cloister is occasionally used as a film set or as a venue for festivals, and frequently serves as an exhibition space for contemporary art.
The Abbey and the wall painting cycle attract numerous visitors from the Czech Republic and abroad throughout the year. In addition to individual tourist visits, guided tours are offered for groups from kindergartens, schools and universities. Visits are possible on site, while limited insight is also provided via the Abbey website. Through the launch of the project website, broader remote access will be provided, including a virtual tour through the cloister, information on iconography, and access to research results. For on-site visits, the Abbey is open from Monday to Saturday, 11:00 to 17:00, from May to October. From November to April, shortened opening hours apply: Monday to Friday, 11:00 to 16:00.
Since 2022, Emmaus Abbey has also been the subject of interdisciplinary research within the DBU-funded project. This has involved regular research activities in the cloister, including the temporary installation of scaffolding. The Abbey administration is responsible for the care and maintenance of the building. The cloister is cleaned weekly, and scaffolding is occasionally required for inspections and minor maintenance or construction work.

7.1.3 Identified User Groups and Access to Spaces

Emmaus Abbey is used by a wide range of groups. As part of the assessment, the following user groups were identified:

- monks
- worshippers and church visitors
- employees of the Abbey administration
- staff and clientele of the rented rooms
- tourists

- school, university and kindergarten groups
- singing groups
- researchers
- external service providers, including maintenance staff, craftspeople and conservators
- artists
- film teams
- conference participants
- event organisers

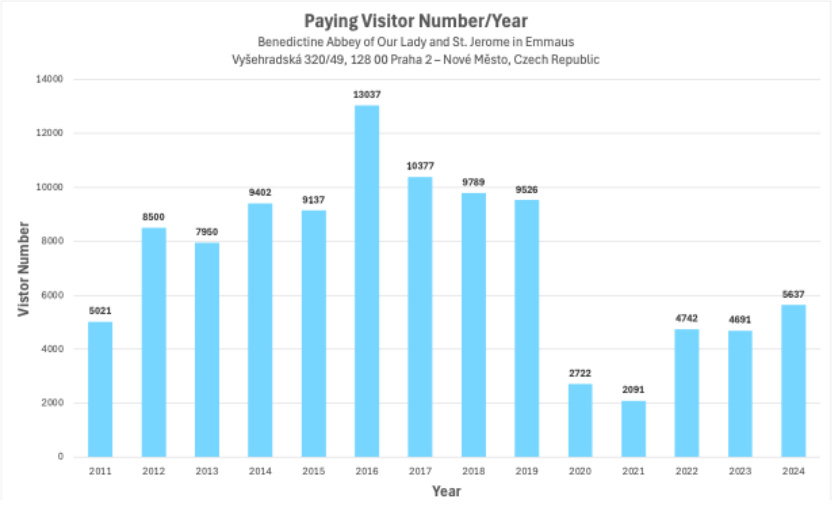
All identified user groups may access the cloister, although frequency, purpose and duration of use differ. The overview of use and access to spaces of Emmaus Abbey by identified user groups is provided in Table (Table 4).

Table 4: Use of and access to spaces of the Emmaus Abbey by identified User Groups, based on information provided by the Abbey administration ©Rebecca Tehrani.

Floor	room	Monks	worshippers / church visitors	Employees of the Abbey administration	Staff and clientele of the rented rooms	Tourists	School, university and kindergarten groups	Singing group	Researchers	External service providers	Artists	Film Team	Conference participants	Event organisers
Ground	Entrance / ticket shop				x	x	x	x	x	x	x	x	x	x
	Chapel	x	x	x		x	x		x	x	x	x	x	x
	Refectory	x		x				x	x	x	x	x	x	x
	Cloister	x	x	x	x	x	x	x	x	x	x	x	x	x
	Courtyard	x	x	x	x	x	x	x	x	x	x	x	x	x
	Offices			x										
	Church	x	x	x	x	x	x	x	x	x	x	x	x	x
1st	Enclosure	x												
2nd	Rented rooms			x	x									
3rd	Rented rooms			x	x									
attic	Attic with Accommodations	x		x					x	x				

7.1.4 Visitor Development and Ticket Sales, 2011–2024

The analysis of ticket sales between 2011 and 2024 shows a marked increase until 2016, when the highest recorded value was reached. This peak can be linked to major cultural events, particularly the exhibition held at Emmaus Abbey to mark the 700th anniversary of the birth of Charles IV. Ticket sales declined after 2017 and dropped significantly during the Covid-19 pandemic, reaching their lowest point in 2021. Since 2022, a gradual recovery has been observed, although the 2024 level had not yet returned to the pre-pandemic level.



Year	Visitor number (paying visitors)
2011	5021
2012	8500
2013	7950
2014	9402
2015	9137
2016	13037
2017	10377
2018	9789
2019	9526
2020	2722
2021	2091
2022	4742
2023	4691
2024	5637

Chart 1: Monthly ticket sales at Emmaus Abbey in 2024, based on data provided by the Abbey administration. Graph: © Rebecca Tehrani.

7.1.5 Movement Patterns and Frequented Areas in 2024

In 2024, the Abbey administration recorded approximately 28,000 users and visitors passing through the Abbey and cloister. Based on the Abbey's assessment, the actual number is likely to have been closer to 30,000, as some user groups were not fully recorded, including visitors who attended church services before entering the cloister. The largest proportion comprised tenants and their clientele, followed by participants in concerts and conferences, paying visitors, and visitors attending services in the Imperial Chapel.

Based on information provided by the Abbey administration, the south and west walks of the cloister represent the most frequently used circulation routes, although all user groups may, in principle, move throughout the entire cloister. These typical movement patterns are relevant to the assessment of use-related risks because they identify areas where repeated passage, temporary crowding, accidental contact with the wall paintings, or the movement of equipment are more likely to occur. The information therefore provides an important basis for evaluating visitor management, operational activities, and other anthropogenic factors relevant to the long-term preservation of the wall paintings.

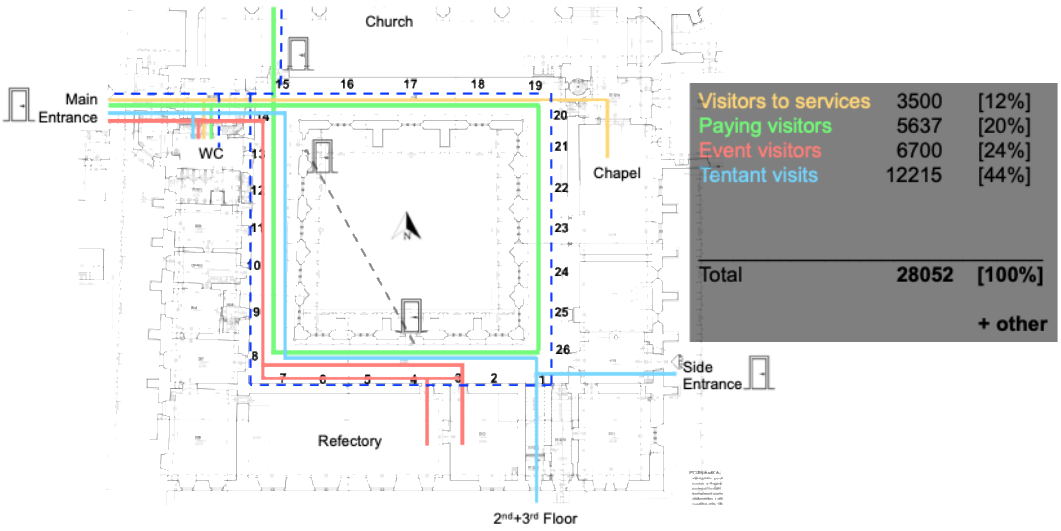


Figure 41: "Typical routes" in the Emmaus Abbey, ground floor. Floorplan C3.1 ©Archiprak –Projectová Kancelár M.G. Parma 2010 (modified by Rebecca Tehrani).

7.1.6 Ticket Sales Seasonality and Group Size in 2024

The detailed analysis of ticket sales in 2024 showed a clear seasonal pattern. Higher visitor numbers were recorded during the main visitor season, particularly in May, August, and October, while lower numbers occurred during the winter months. The higher visitor numbers reflect longer opening hours, increased tourist activity, and public holidays. In May 2024, several peaks corresponded with public holidays, weekends, and organised group visits (Chart 2).

Large groups were comparatively rare but could reach considerable sizes, with the largest recorded group comprising 82 people. Such groups are relevant to the environmental and risk assessment because they may result in temporary crowding, increased movement close to the painted surfaces, a greater likelihood of accidental contact, and short-term increases in humidity within the cloister.

The 2024 ticket sales data also record the language of the printed guide issued with each ticket. Czech was the most frequently requested language, followed by English, while German, French, Spanish, and Russian accounted for smaller proportions (Chart 3). These data should not be interpreted as indicating visitors' nationality or first language, but they provide a useful indication of the languages requested for

on-site interpretation. The results also support the current provision of interpretative information in Czech and English and may assist future decisions concerning multilingual visitor information.

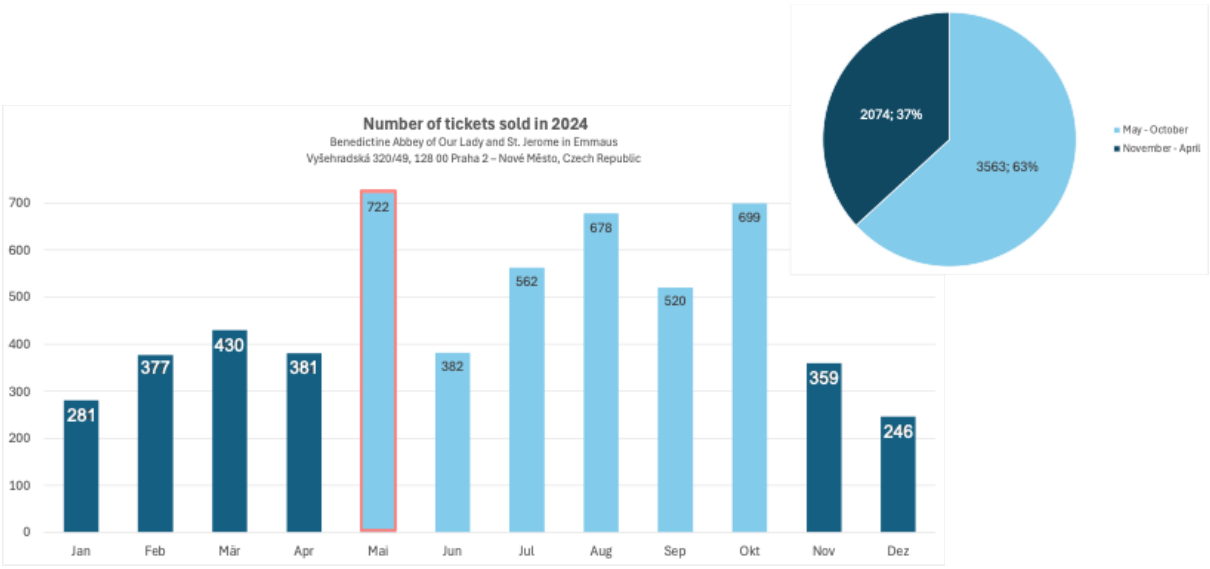


Chart 2: Survey of paying visitors in 2024 per month, based on data provided by the Abbey administration; Graph ©Rebecca Tehrani.

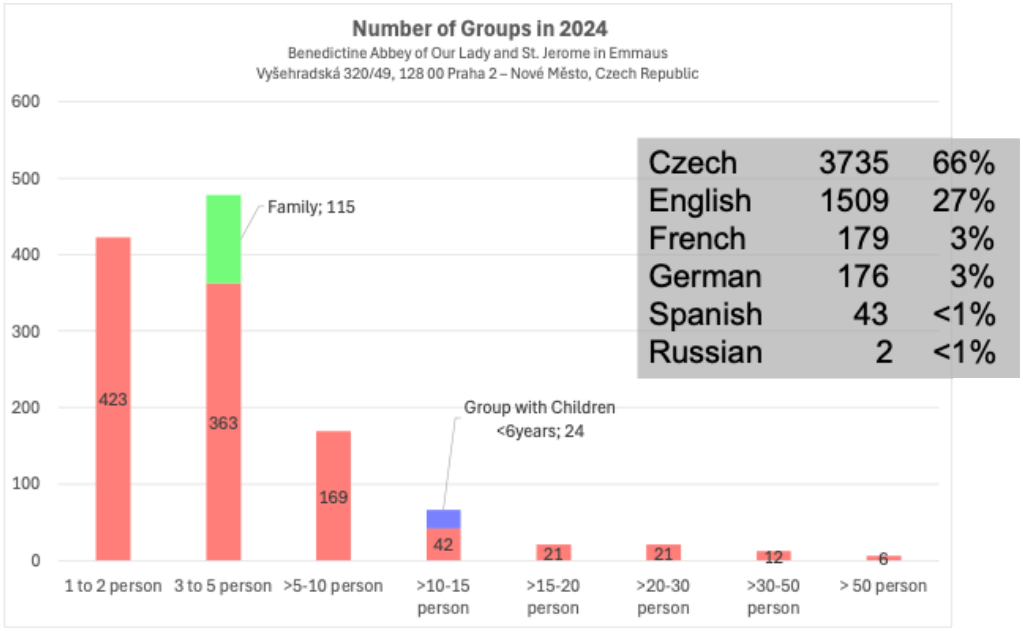


Chart 3: Ticket sales in 2024 by group size and recorded guide language, based on data provided by the Abbey administration. Graph: © Rebecca Tehrani.

7.1.7 Implications for Future Planning and Risk Reduction

The assessment of current use indicates that the wall-painting cycle is situated within a cloister that continues to serve as an integral part of the living Emmaus Abbey. The space is used by the monastic community as well as by visitors, researchers, contractors, and other user groups for a range of religious, operational, educational, and cultural activities. Consequently, the cloister is not entered solely for the

appreciation of the wall paintings but also functions as an important circulation and activity space within the Abbey.

Future planning for the presentation, maintenance, and long-term safeguarding of the wall-painting cycle should therefore seek to balance the continued use of the cloister with the requirements of preventive conservation. Different patterns and intensities of use present different levels of risk. Frequently used circulation routes may increase movement near painted surfaces, while larger groups may lead to temporary crowding, an increased likelihood of accidental contact, and short-term increases in humidity.

Events involving catering, filming, maintenance, or research activities may require equipment, temporary installations, scaffolding, or prolonged occupation of the space and should therefore be subject to clear conditions and prior coordination. Such activities may affect the cloister's indoor environment and, consequently, the long-term preservation of the wall paintings. These factors should be considered when planning visitor management, maintenance activities, access arrangements, and future conservation measures.

7.2 Questionnaire on Current Heating and Ventilation Practices at Emmaus Abbey

In May 2025, the TH Köln Team sent a questionnaire on current heating and ventilation practices at Emmaus Abbey to the Abbey administration. The questions were provided in English and Czech. The responses were received from representatives of the Abbey administration in Czech and translated into English for the project documentation. The correspondence and translation process were supported by UPCE.

The questionnaire addressed the operation and control of the heating system, the heating of rooms adjacent to the cloister, the regulation of radiators and thermostats, heating practices during weekends, holidays and events, and current ventilation routines. The aim was to document use-related practices that may influence the environmental conditions in and around the cloister and, therefore, be relevant for the assessment of risks to the wall paintings.

According to the responses, the Abbey is generally heated from October to May, with no heating during the summer months. The south and west sides of the ground floor are tempered, and the chapter hall is equipped with underfloor heating set to a low temperature. The heating system is operated by an automatic boiler controlled by a thermostat and regulated according to outdoor temperature. Radiators are fitted with thermostatic valves and adjusted individually by Abbey staff. During weekends and holidays, the heating is reduced rather than switched off.

No separate heating regime for special events, such as conferences or concerts, was reported. The Refectory and adjacent rooms are heated by radiators, and temperatures are not specifically adjusted before or after events. Observations made during research activities indicate that radiators in these spaces are accessible to authorised users, including researchers and event organisers, and may therefore be adjusted during their use.

Ventilation is achieved naturally, primarily by opening windows and doors. According to the responses, ventilation is undertaken by Abbey staff, and no formal ventilation plan exists. No rooms were reported to be deliberately excluded from ventilation or to be subject to specific ventilation measures for sensitive equipment, artworks, or heritage protection.

7.3 Evaluation of Historical SO_2 Data

As part of the environmental assessment, historical SO_2 data were reviewed in order to contextualise the outdoor air pollution situation in the wider urban environment of Emmaus Abbey. The evaluation

focused on the development of SO_2 concentrations over time and on their relevance as contextual information for assessing past and present environmental conditions affecting the wall painting cycle. The aim of this section is to document the available data and to provide a basis for interpreting the possible relevance of past pollutant exposure for the current preservation context of the wall paintings. The data do not represent measurements inside the cloister and cannot be used to reconstruct the actual pollutant exposure of the wall paintings. They are therefore used as contextual evidence for the broader outdoor SO_2 situation in Prague.

7.3.1 Data Sources, Evaluation Method and Limitations

The SO_2 values used for the evaluation were obtained from the annual online tables published by the Czech Hydrometeorological Institute (CHMI), *Air Pollution and Atmospheric Deposition in Data, the Czech Republic: Annual Tabular Overview*. The overview page provides access to annual datasets from 1997 to 2024. (https://intranet.chmi.cz/files/portal/docs/uoco/isko/tab_roc/tab_roc_EN.html).

The methodological basis for using these data was checked against the CHMI report *Data Collection, Processing and Evaluation Systems in 2021* by L. Vlasáková and H. Škáchová, published in 2022. This report describes the Air Quality Information System Department as responsible for the collection, processing and archiving of data within CHMI. It also states that air quality data and related metadata are stored by CHMI and describes a two-step verification process for air pollution data before publication.

The monitoring station Praha 2 – Riegrovy sady was selected because it is the nearest available CHMI station to Emmaus Abbey. The selected data record SO_2 concentrations in µg/m³. According to the station metadata, Praha 2 – Riegrovy sady is a stationary automatic air quality monitoring station. SO_2 is measured by UV fluorescence at a 30-minute measurement interval. The station was established on 22 August 1991, and SO_2 measurements began on 19 February 1992. However, the annual online tables identified and used for this evaluation start in 1998. The assessment therefore covers the period from 1998 to 2024. Data later than 2024 is not yet available.

The raw data were available in different formats across the years. They were therefore compiled and systematised in Excel before further evaluation. This step was necessary to create a consistent dataset and to allow comparable analysis across the full period. The processed dataset was then used to prepare a graph showing daily, monthly and annual SO_2 average concentrations in µg/m³.

The evaluation has several limitations. The data represent outdoor SO_2 concentrations at a nearby monitoring station and not measurements inside Emmaus Abbey or the cloister. They therefore provide contextual information on the broader urban air pollution situation in Prague rather than direct exposure values for the wall paintings. In addition, the dataset used for the evaluation starts in 1997, although SO_2 measurements at the station began earlier according to the station metadata. The data cannot therefore be used to reconstruct the full historical pollutant exposure of the wall paintings or to establish a direct causal link between SO_2 concentrations and specific alteration phenomena. Their purpose is to provide a comparable long-term reference for the outdoor SO_2 situation in the wider urban context of Emmaus Abbey.

7.3.2 Development of SO_2 Concentrations, 1998–2024

The evaluated data demonstrate a clear long-term decline in outdoor sulphur dioxide (SO_2) concentrations at the CHMI monitoring station *Praha 2 – Riegrovy sady*. Higher daily and monthly concentrations are evident during the earlier years of the record, whereas annual mean values decrease markedly over time and remain consistently low in the later years. These results indicate that current

outdoor SO_2 concentrations in the wider urban environment surrounding Emmaus Abbey are substantially lower than those recorded during the late 1990s and early 2000s (Figure 42).
A distinct seasonal pattern is also evident, with higher SO_2 concentrations during the colder months, which broadly correspond to the heating season (Figure 42). According to CHMI, anthropogenic emissions associated with heating are temperature-dependent and generally increase during the cold half of the year. The institute also notes that ambient air pollutant concentrations are influenced not only by emission sources but also by meteorological and atmospheric dispersion conditions, including temperature stratification, wind speed, and vertical mixing. The observed seasonal increases in SO_2 concentrations should therefore be interpreted as the combined effect of higher combustion-related emissions and less favourable winter dispersion.

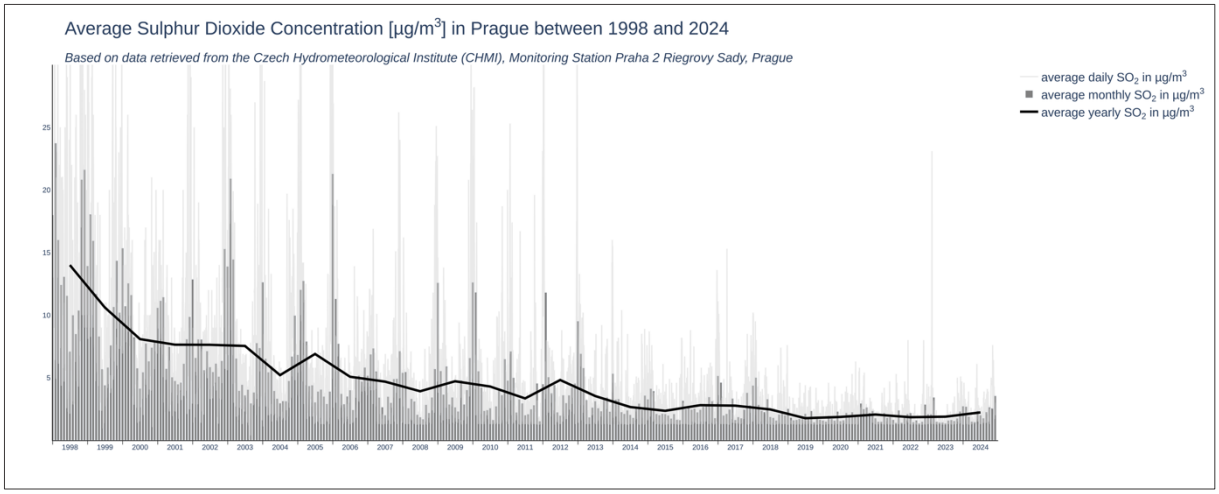


Figure 42: Average daily, monthly and annual SO_2 concentration in Prague between 1998 and 2024, based on data from the CHMI monitoring station Praha 2 – Riegrovy sady. Data processing and graph: © Rebecca Tehrani, David Riedel.

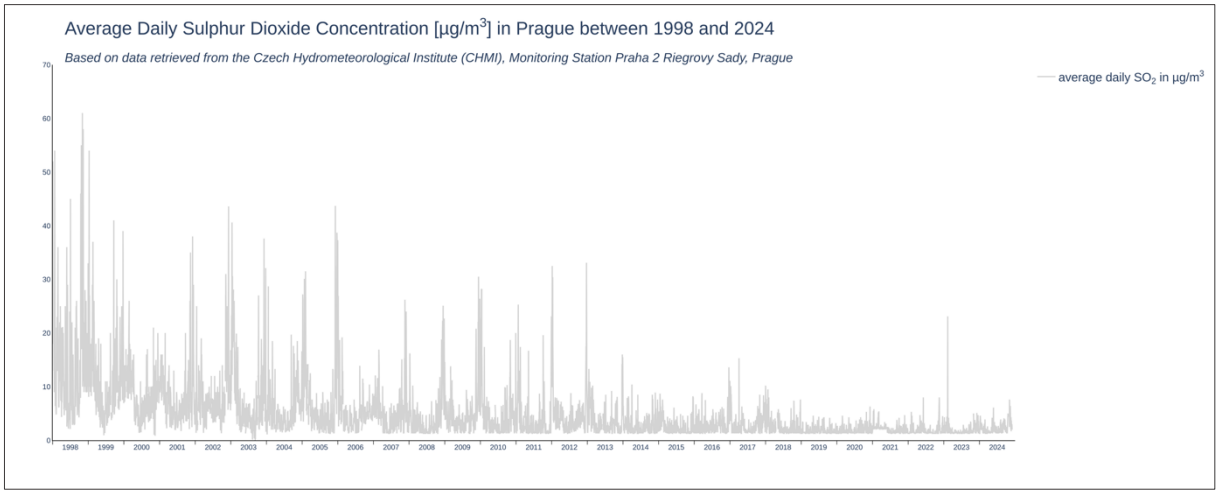


Figure 43: Average daily, SO_2 concentration in Prague between 1998 and 2024, based on data from the CHMI monitoring station Praha 2 – Riegrovy sady. Data processing and graph: © Rebecca Tehrani, David Riedel.

7.3.3 Relevance for the Environmental Assessment

For the environmental assessment, the SO_2 data provide contextual evidence rather than direct measurements of pollutant exposure. They indicate that current outdoor SO_2 concentrations in the vicinity of Emmaus Abbey are substantially lower than those recorded earlier in the evaluation period. This suggests that present-day outdoor SO_2 exposure is unlikely to represent the same level of risk as in previous decades. The data do not demonstrate that SO_2 caused specific deterioration phenomena

affecting the Emmaus Cycle. They do, however, support the interpretation that higher historical levels of air pollution may have contributed to sulphate-related deterioration processes, particularly before the monitoring period covered by the available data. This interpretation should be considered alongside the results of material analyses, condition surveys, conservation history, and historical evidence relating to the opening and glazing history of the cloister. The SO_2 data therefore provide long-term contextual information on outdoor air quality in Prague from 1998 onwards. They do not represent pollutant concentrations within Emmaus Abbey or the cloister itself. Potential local or building-related sources of pollutants, including the Abbey's historical heating systems, are therefore considered separately in the following section.

7.4 Historical Heating Systems and other Pollutant Sources

The historical development of the heating systems at Emmaus Abbey was investigated to identify potential building-related sources of pollutant exposure relevant to the condition of the wall paintings. This review complements the assessment of outdoor SO_2 concentrations presented in the previous section, but does not provide direct evidence of pollutant concentrations within the cloister or of the actual exposure of the wall paintings.

The assessment was based on archival material, including historical heating plans, historical photographs and documentation provided by the Emmaus Abbey administration, as well as on-site observations. This section summarises the sources and observations relevant to the environmental assessment. It does not constitute a full technical or archival history of the heating systems at Emmaus Abbey. More detailed information will be presented separately in a forthcoming publication.

Today, the Abbey uses a water-based central heating system. Since 1996, the system has been operated with gas; before this conversion, it was fuelled by coal. The coal was formerly stored on the western slope of the Abbey, where a car park is now located. The heating period generally runs from October to May, although it may be extended or shortened depending on the weather.

The current heating system was installed between 1957 and 1961 as part of the post-war reconstruction. The design was submitted by SÚRPMO in 1956 and approved by the building trade union in 1957. The heating plan from 1957 documents a coal-fired central heating system supplying rooms on the east, south and west sides around the cloister. The pump and boiler are located in the basement beneath the cloister and courtyard. In August 2012, hot water pipes were replaced during renovation work in the cellar and in the shafts beneath the cloister.

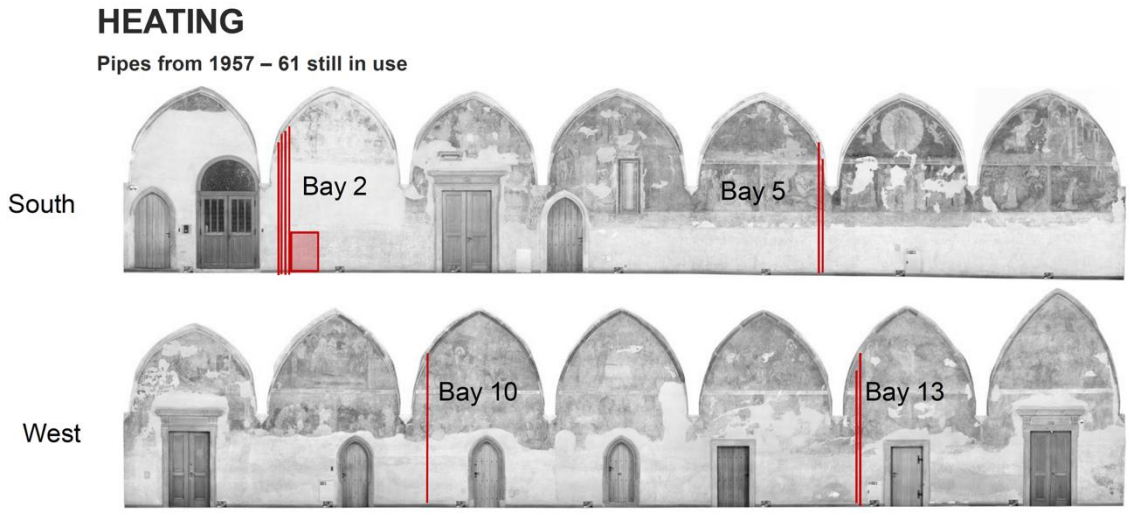


Figure 44: Red lines show hot water pipes/radiators of today's heating system in adjacent rooms/backside of the wall paintings. Orthophotography © Jiří Vidman, Pavel Hlavenka. (Modified by Rebecca Tehrani)

The layout of pipes and radiators documented in the 1957 heating plan was reviewed in relation to the current situation and during an inspection in March 2025. According to the current findings, the general layout has largely remained unchanged since its installation. Rooms in the west and east walks of the cloister are heated with radiators, while the chapter hall is warmed by underfloor heating. Underfloor heating was also introduced in the sacristy in 1994.

Hot water pipes run to rooms equipped with radiators, typically along the outer walls, for example, in the refectory. This configuration stems from decisions made during the 1956/57 post-war reconstruction and was criticised in a 1985 building survey because of its impact on the medieval fabric. On the first floor, radiators and hot water pipes are installed, heating the rooms surrounding the cloister on the east, south, and west walk. The warm water pipes and radiators on the first floor are still in the same positions today. They run above the cloister vaults, with some pipes and radiator located directly or in close proximity above the bays decorated with the Emmaus Cycle or the painted vaults.

The position of hot water pipes and radiators in adjacent rooms corresponds with the surface temperature measurements and helps to explain local temperature differences in the cloister, including the comparatively high measured temperatures in Bay 2. Since the pipes carry water and are located above or near decorated areas, they are also relevant for the assessment of potential water-related risks (Figure 44).

In addition to the conventional pipe and radiator system, a Crittall radiant heating system was installed beneath the cloister floor as part of the heating works carried out between 1957 and 1961. This system provided radiant heat to the cloister from below. It was a low-temperature, large-surface radiant heating system in which warm water circulated through pipes integrated into horizontal building structures. At the time, it represented a relatively new and costly technical solution.

The installation of the Crittall system required extensive construction work in the cloister, including excavation across the width of the walk, concreting, tiling, brickwork and work on the vaults. Conservation and building sources from the 1960s and 1980s indicate that the system was viewed critically, both because of the interventions required for its installation and because of its possible effects on the wall paintings.

In 1966, an expert commission criticised the combined effect of the Crittall heating system, ventilation shafts and the use of the cloister at the time. The cloister was used as a circulation route and, at times, as a storage area for devices, tools and furniture by institutions occupying the Abbey building. According to the commission, dust and dirt introduced through this use could be mobilised by the floor heating and deposited on the newly restored paintings. Later conservation reports again referred to problems associated with dust and dirt in the cloister and recommended measures such as a more washable floor surface, improved access routes, frequent wet cleaning and vacuuming of the cloister floor, and regular cleaning of the windows opposite the wall paintings.

Information on the Abbey's heating system before the bombing of 15 February 1945 is limited and fragmentary. Historical photographs from 1911, 1945, and 1957 show ventilation shafts in the floor near the northern and western walls of the cloister. These features most likely relate to earlier heating or ventilation infrastructure and may indicate the existence of a coal-fired central heating system before the post-war reconstruction. Additional historical sources point to earlier local heating systems, including tiled stoves, fireplaces, and coal storage facilities.

Heating was not the only potential source of pollutants within the cloister. Historical documentation also indicates long-term use-related sources of airborne contaminants and surface deposits. A photograph taken in 1964 shows an ashtray near the entrance to Bay 8, indicating that smoking occurred within the cloister. In 1988, the conservator Jiří Blažej recommended a complete ban on

smoking because tobacco smoke could leave a brown film on the wall paintings. Taken together, these observations suggest that smoking was tolerated within the cloister over an extended period and may have contributed to the gradual accumulation of tobacco-derived particulates and organic residues on the painted surfaces. Although the extent of this contribution cannot be quantified, it represents a plausible additional source of long-term indoor pollution that should be considered alongside combustion-related emissions from historical heating systems.

The study indicates that successive heating systems may have influenced the environmental conditions of the cloister and adjacent rooms in different ways. Earlier stove-based heating, coal-fired heating systems, and the former coal-fired central heating system represent plausible historical sources of combustion-related pollutants, including SO_2. However, because no corresponding measurements of pollutant concentrations within the cloister are available, their contribution to the exposure of the wall paintings cannot be quantified.

The conversion to gas heating in 1996 substantially reduced the likelihood of comparable SO_2 emissions from the Abbey's own heating system. The current arrangement of radiators and hot-water pipes is relevant to interpreting measured surface temperature differences and assessing potential water-related risks. Likewise, the documented concerns regarding the Crittall radiant heating system, dust mobilisation, and long-term indoor smoking provide important historical context for understanding the accumulation of surface deposits, past deterioration processes, and the rationale for earlier conservation interventions. Together, these observations contribute to the environmental assessment by identifying plausible sources of pollutants, operational factors, and building-related risks relevant to the long-term preservation of the wall paintings.

7.5 Liquid Moisture Survey

As part of the environmental assessment, the Liquid Moisture Survey focused specifically on liquid water, past, present and potential future, in relation to the building envelope and its possible impact on the condition of the wall paintings. Understanding liquid moisture conditions is essential for interpreting the condition assessment and for determining whether further environmental monitoring, maintenance or other measures are required. In this context the building envelope is understood as the physical separator between the interior and exterior environments of the Abbey (cloister). It includes the foundations, roof, walls, doors, windows and other openings. The materials, construction, connections and interactions between these components are relevant for understanding how liquid water may enter, move through or affect the building.

The Liquid Moisture Survey was documented using photographs, drawings and plans. All observations were non-invasive. The assessment considered the environmental context and the physical use of the cloister, as well as relevant adjacent rooms and building elements.

The survey included on-site inspection, the checking of potential water sources and routes of water flow, and the assessment of relevant building elements, including gutters, rainwater pipes, roof connections, drainage details, walls, floors, openings and adjacent rooms. Historic information, including evidence of previous water damage, was also considered where available, supplemented by information provided by the Emmaus Administration and by the review of internal documentation.

7.5.1 Sources Used for the Evaluation of Past and Present Liquid Water

The evaluation of past and present liquid water was based on several complementary sources. These included the BA research by Chari-Juliane Tihanyi, subsequent on-site campaigns and visits by the TH Köln team, historic photographs, internal documentation provided by the Emmaus Administration, and previous technical reports.

The on-site observations were carried out during several project visits, including Tihanyi and Tehrani in April 2024, Tehrani and Heritage in May 2024, and Tehrani in March 2025. These observations focused on potential water sources and routes of water flow, especially in relation to the rainwater system, roof connections, drainage details heating system in adjacent rooms, archival research and visible signs of moisture or salt-related processes.

7.5.2 BA Research

The assessment of liquid moisture was addressed in a BA thesis carried out at TH Köln by Chari-Juliane Tihanyi under the supervision of Adrian Heritage and Rebecca Tehrani. The thesis, submitted on 11 June 2024, was entitled *Die Umfelderfassung als Bestandteil eines Wandmalerei-Erhaltungskonzeptes. Praktische Umsetzung, ausgehend von der "Liquid Moisture Survey", am Beispiel des Emmausklosters in Prag*. The BA research used Emmaus Abbey as a case study and examined several aspects relevant to the Liquid Moisture Survey, including the building and conservation history, the location and topography of the site, access to and use of the Abbey, sun movement, and selected aspects of the building envelope. The research provided a valuable foundation for the assessment of liquid moisture in the context of Emmaus Abbey. This line of investigation was subsequently developed further by the TH Köln team and integrated into the wider environmental assessment of WP6 through additional non-invasive inspections and project documentation.

7.5.3 Previous Moisture Survey: Klokner Institute Moisture Survey Report, 2013

A previous technical reference was the moisture survey of the perimeter walls of the courtyard prepared by the Klokner Institute, Czech Technical University in Prague, in 2013 (*Průzkum obvodových stěn rajského dvora kláštera Panny Marie a sv. Jeronýma v Emauzích z hlediska vlhkosti*, expert report no. 130 102; Balík and Nenadálová 2013).[1] The report addressed the moisture condition of the courtyard walls, where salt efflorescence and moisture-related damage had been observed in the plinth zone.
It was provided by the UPCE team and translated into English for the project.
The report was based on visual inspection, photographic documentation, the review of available documentation, indicative moisture measurements with a capacitive moisture meter, gravimetric moisture analysis and sampling for salt ion analysis. The on-site survey was carried out on 8 April 2013. The report identified the following relevant observations:

- the perimeter walls of the courtyard, on the side of the cloister walk, did not show visually apparent moisture, with the exception of the central part of the western perimeter wall;
- on the courtyard side, a marked increase in visible moisture marks was observed mainly around door openings to the cloister walk, particularly on the western and southern façades, reaching up to approximately 3 m in height;
- the plaster of the courtyard walls was mechanically degraded in the plinth zone, in many areas up to the level of the window sills and along almost the entire perimeter;
- at the points where rainwater pipes discharged into the roof-water collectors, a distinct increase in moisture was observed, accompanied in places by green mould or algae;
- moisture impact was also visible below the roof cornices on several courtyard façades.

The moisture measurements indicated that increased to very high moisture values were mainly concentrated in the lower wall areas, predominantly up to approximately 300 mm above floor or ground

[1] Lukáš Balík and Šárka Nenadálová, *Průzkum obvodových stěn rajského dvora kláštera Panny Marie a sv. Jeronýma v Emauzích z hlediska vlhkosti*, expert report no. 130 102, České vysoké učení technické v Praze, Kloknerův ústav, Prague, 12 July 2013, unpublished report.

level. The exterior side of the courtyard walls showed a less favourable moisture condition than the cloister-side interior.

→ moisture condition observed in 2013:

- rainwater splashes wetting the base of the masonry in the plinth area
- rainwater from damaged downpipes
- rainwater accumulating in the depressions and cracks in the concrete walkway along the perimeter walls
- rainwater retained in depressions and cracks in the concrete walkway along the perimeter walls
- rising damp from the subsoil
- condensation on the surface of the masonry in the cloister walk
- direct penetration of soil moisture into the exterior masonry below ground level.

→ salt analysis results

- To determine the salt content in the masonry, six samples were taken from the exterior walls (masonry and plaster) and then chemically analysed. The tests were carried out in accordance with EN ISO 10304-1.
- The results of the chemical analysis of the sampling show that the quantity of all analysed salts contained in the masonry is low (the low value according to ČSN P 73 0610 is not exceeded). In all cases of chloride, nitrate and sulphate, analysed according to the same standard (low content)

For the present project, the Klokner Institute report is considered as a contextual source for the understanding of the wider context. Its findings relate primarily to the courtyard façades and the plinth zone and not to the wall paintings themselves. No direct water-related damage to the wall paintings was observed during the project. Nevertheless, salt efflorescence in the plinth zone of the courtyard walls and inside the cloister remain visible, which forms a part of the building envelope, and was therefore considered as part of the Liquid Moisture Survey.

7.5.4 Internal Documentation: Water-Related Events and Building Works

As part of WP6, the *Emauzy kronika* was reviewed in order to better understand the building history, technical installations, heating system, use of the Abbey, and events relevant to the environmental assessment. The *Emauzy kronika* was compiled by the Emmaus Administration and functions as a form of internal documentation. It contains photographs, flyers, handwritten notes, newspaper articles, and records of events, repairs and building works. At the time of review, the available documentation covered the period from 1990 to 2024. For its translation into German and English Google translate was used and the results were verified through the close exchange with members of the UPCE Team.

For the Liquid Moisture Survey, the reviewed material was assessed specifically for references to water-related events, works and building envelope works, drainage, roof repairs, technical services, courtyard conditions and adjacent building areas (Table 5).

Table 5: Selected entries from the Emauzy kronika (1990-2024) considered in relation to the Liquid Moisture Survey (past water). Research and organisation of information © Rebecca Tehrani.

Year / date	Location / area	Event or observation	Source
1991–1995	Church	Annual art exhibitions took place in the church.	Emauzy kronika 1990–1997, p. 60.
1992–late 1990s	Roof	Beginning of extensive roof repairs. According to the internal documentation, experts considered the roofs of the abbey to have already been in a state of disrepair in the 1980s. Repairs started with the church roof and were subsequently continued.	Emauzy kronika 1990–1997, p. 46.

Year / date	Location / area	Event or observation	Source
Mid-December 1992–end April 1993	Ground floor, church	The main nave was paved with concrete; the floor was covered with terrazzo.	Emauzy kronika 1990–1997, pp. 29–30.
January 1993	First floor, former offices	Former offices were divided into cells; each cell was equipped with a small kitchen and bathroom.	Emauzy kronika 1990–1997, pp. 30–31.
March 1993	Roof inspection	Inspection of the roof noted tiles and rubble in the gutter on the south side of the abbey. The north side of the church was described as being in good condition. Tiles and rubble were also noted in the gutter where the south-western roofs meet.	Emauzy kronika 1990–1997, pp. 31–32.
12 April 1993	Church and chapel	Celebration of the restored Imperial Chapel.	Emauzy kronika 1990–1997, pp. 34–35.
1993	Electricity	Reconstruction of the transformer station. The old transformer had to be replaced and adapted to new standards.	Emauzy kronika 1990-1997, p. 46.
1994	Water supply	Renewal of the water supply system and sanitary facilities in the old cloister, parallel to building works on all floors, including cells and offices.	Emauzy kronika 1990-1997, p. 46.
1994 / 1995	Sacristy	Renovation work in the sacristy included the installation of floor heating and marble flooring.	Leaflet from 1994; Emauzy kronika 1990–1997, pp. 49, 55.
1996	Heating	The building of the former skin clinic was reconstructed for the Cosmetic Institute. The central boiler room located in the basement under the Cosmetic Institute was rebuilt. Heating with solid fuels, coal, was replaced by gas heating.	Emauzy kronika 1990–1997, p. 64.
1998–1999	Parking area; information on historic heating system	Paving works were carried out on the parking area below the western side of the abbey. The entry also refers to the former use of this area for coke storage during the operation of the solid-fuel boiler room; after conversion to gas heating, the area could be used for other purposes (note: purposes not mentioned)	Emauzy kronika 1997–2008, p. 13.
25 June–20 September 2010	Exhibition in the abbey	Exhibition with 23 panels, mostly 70 × 100 cm, borrowed from the administration of the New Town Hall. The form of the exhibition was reduced, as it had originally included three-dimensional exhibits. A separate system was required. For exhibitions in the cloister, lighting was identified as a problem, as daylight was sufficient only in the summer months and only on sunny days.	Emauzy kronika 2009–2013. (Note by the author of the chronicles.)
August 2012	Basement / hot-water supply	Distribution pipes for the hot-water supply to heating elements in the basement and in the channel beneath the abbey were repaired.	Emauzy kronika 2012–2015.
November 2012	Courtyard investigation	Investigations of the foundations of the walls around the Garden of Eden were carried out in preparation for the reconstruction of the garden. At the south wall, a trial trench showed that there was no foundation, only soil.	Emauzy kronika 2012–2015.
24 September 2012	Guided tour, abbey	Book presentation by Kateřina Kubínová.	Emauzy kronika 2012–2015.
May 2013	Electricity / service channel	A new cable was laid from the transformer station below the terrace on the west façade to the main switchboard in the room under the stairs. The cable was routed through the channel along the church and the basement rooms, heating channel, beneath the abbey.	Emauzy kronika 2012–2015.
June 2013	Courtyard	Four further trial trenches were carried out in the courtyard on the west, north and south sides of the wall and in the centre of the garden. Foundation remains of a cross from 1880 were uncovered. On the south side, the building was found to stand directly on rock; towards the north, where the rock was less stable, the building stands on a foundation.	Emauzy kronika 2012–2015.
October 2013	Third-floor windows, abbey	Reconstruction of four roof windows on the western side of the abbey, third floor.	Emauzy kronika 2012–2015.
February–August 2014	Wastewater channels outside the abbey	Wastewater channels outside the abbey were cleaned and repaired. The works were commissioned by Prague City Hall and completed by the Abbey. During exposure of the channels, the ventilation channel was inspected in August 2014.	Emauzy kronika 2012–2015.
Mid-September 2014	Cell 10 leakage	Room 10 and the cells above were heated. A defect water supply to the boiler in the cell led to a leak. The wetting of the parquet floor in room 10 caused lifting in two places and interrupted the use of the room for several months. In March 2015, the final repair of the parquet was postponed, and the floor was temporarily covered with carpet. (Note: direct influence on refectory and adjacent wall painting bays in the south walk)	Emauzy kronika 2012–2015.

Year / date	Location / area	Event or observation	Source
Spring 2015	Cloister	For filming the film "Verbrechen in Polen", different lamps were installed in the cloister walk.	Emauzy kronika 2012–2015.
2020	Entrance hall / conversion	Completion of accessible toilet, kitchen and cloakroom, small chamber and reception desk; camera system extended.	Emauzy kronika 2019–2021.
March–April 2022	First floor above the cloister	A row of cells on the south side was renovated. Sanitary facilities and kitchens were installed.	Emauzy kronika 2022–2024.
End June–end September 2022	Roof, east wing of the abbey	The already deteriorated roof covering was replaced, and sheet-metal works were carried out.	Emauzy kronika 2022–2024.
November 2022	Portal between cloister and Garden of Eden	The portal was repaired by a stonemason. Damaged brickwork had pressed onto the sandstone lintel, and the threshold was also damaged, which led to leaks into the cloister.	Emauzy kronika 2022–2024.

The historic photographs collected and organised in WP2 were also reviewed for visible evidence of past water infiltration, water-related damage or possible sources of liquid water. The only clearly identifiable indication was water in the cloister walk after the air raid in 1945. The phenomena "traces of dripping" observed during the visual inspection in WP3, particularly in bay 16(16+17), were considered in relation to possible water ingress associated with the war-related damage.

The following observations summarise the principal potential sources of liquid water identified during the on-site inspection and their relevance to the long-term preservation of the wall paintings.

Potential sources of liquid water and associated risks were assessed in the exterior areas, the cloister, adjacent accessible rooms, the upper floors, roof spaces, and the attic. The inspection was entirely non-invasive and focused on visible evidence, accessible parts of the building, and information provided by the Abbey administration. The monks' rooms on the first floor and the rented rooms on the second and third floors were not accessible.

Rainwater system: The rainwater system was inspected as far as possible, supported by zoom photography. No obvious defects were observed during the inspection. According to the Abbey administration, the rainwater system is regularly inspected and maintained by external companies commissioned by the Abbey. Regular inspection and maintenance of gutters, rainwater pipes, and roof drainage remain important, as previous documentation shows that blocked or damaged rainwater systems have influenced moisture conditions in the courtyard and adjacent masonry.

Salt efflorescence in the west walk: Salt efflorescence was observed close to floor level in the west walk, on both sides of the door in Bay 13(13). The efflorescence was not located on the painted surface. The affected area lies adjacent to the accessible toilet. Service pipes also run below or close to this area, supplying both the accessible toilet and the toilets in the entrance area. According to oral information provided by the Abbey administration, a water-damage incident occurred in this area several years ago and has since been repaired. Apart from this local observation, no salt efflorescence indicative of active transport of soluble salts through the painted areas was observed on the cloister side of the wall paintings. Salt efflorescence was, however, observed in the courtyard plinth zone and on the courtyard-facing walls of the cloister, corresponding to the areas already described in the Klokner Institute report (2013).

Basement areas and water-bearing installations: Salt efflorescence was also observed on the walls in the basement below the cloister, where the heating system is located. One level below the heating system, historic basins formerly used for storing lime putty remain in situ, although they are no longer in use. These basins may be relevant when considering possible local sources of soluble salts within the masonry. Previous incidents demonstrate that defects in water-bearing services, including heating and sewage pipes, represent potential risks of liquid-water damage (Table 5). The location of these installations was documented photographically and by mapping (Figure 44). Water-bearing pipes running externally along the walls are located on the ground floor in rooms adjacent to the cloister,

directly behind Bays 2(2), 5(5), 10(10), and 13(13) in the south and west walks. In addition, pipes and radiators are located on the first floor directly above both the painted vaults and the same bays of the Emmaus Cycle. The mapping was based on visible installations and the historic heating plan of 1957, as the heating system and its pipe routes remain in use. Although no active leakage was observed during the inspection, the documented water incident in Room 10 and the proximity of water-bearing services to, behind, and above the painted areas underline the importance of including these installations within future inspection, maintenance, and monitoring programmes. Even defects in pipes or radiators that are not located directly behind the Emmaus Cycle may affect decorated areas of the cloister, since the vaults are also painted.

Wet floor cleaning: According to information provided by the Abbey administration, the cloister floor is wet cleaned approximately every two weeks. Wet floor cleaning was also observed during a project visit. Cleaning is carried out up to the walls of the cloister. A cleaning product used for this purpose was documented; the container was labelled *Kärcher FloorPro CA 50 C eco!perform*. The regular use of water and cleaning agents represents repeated moisture input at floor level and along floor–wall junctions, particularly where liquid may remain in contact with porous materials such as plaster or mortar joints. Apart from the salt efflorescence already described no direct water-related damage to the wall paintings was observed in connection with the cleaning routine. Although no painted plaster survives in the lower wall zone, wet cleaning may contribute to the transport of soluble salts and local increases in relative humidity and should therefore be considered in relation to preventive measures and maintenance procedures.

Use, visitors, and temporary events: The use of the cloister can contribute to temporary increases in humidity. Moisture may be introduced by visitors through respiration, wet clothing, and footwear, particularly during wet weather and when larger groups are present. The effect depends on the number of people, duration of stay, ventilation, air exchange, room volume, and the moisture-buffering capacity of the building materials. The use of Emmaus Abbey is documented in a logbook. Additional temporary moisture sources may occur during events. Warm catering, especially during conferences or similar events, can introduce moisture into the indoor environment. A filming event in July 2024 was also identified as relevant following review of the micro-climate monitoring data and subsequent enquiry with the Abbey administration. According to the Abbey administration, water vapour was used to generate artificial fog during this filming event; this activity had not been recorded in the logbook. Such temporary activities should therefore be considered as possible short-term sources of moisture, particularly where they take place in or near the cloister.

Potted plants in the cloister: During the winter period, potted plants are placed in the cloister, primarily in the north and east walks. During the summer they are kept outdoors. The temporary storage of potted plants may represent a minor local source of moisture, depending on watering routines, drainage from pots or saucers, and the distance between the plants and the walls. Based on the observations made during the inspection, this is considered a low-level and localised issue.

Overall, the inspection did not identify direct water-related damage to the wall paintings or evidence of an active, widespread liquid-water problem affecting the painted surfaces. The principal risks identified relate to the wider building context, particularly rainwater management, water-bearing infrastructure, basement conditions, and previously documented water incidents. These are of particular significance because defects in rainwater systems, service pipes, heating pipes, sewage pipes, or radiators located close to, behind, or above the painted areas could result in sudden local water ingress, even where no visible moisture problems are present during routine inspections. Wet cleaning, visitor use, temporary events, and the seasonal storage of potted plants represent additional localised or short-term sources

of moisture. Together, these observations provide an important basis for future maintenance, monitoring, risk management, and preventive conservation planning.

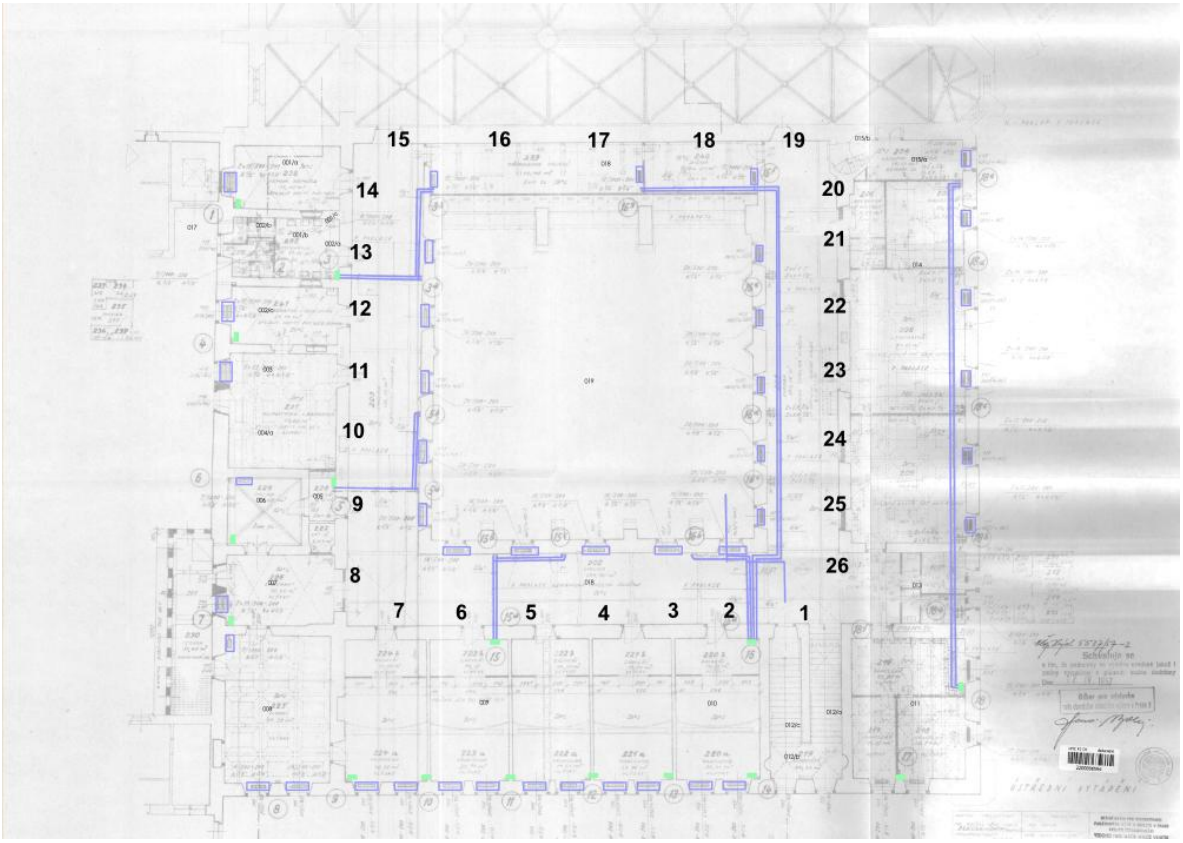


Figure 45: Location of water-bearing installations in relation to the cloister wall paintings. Green indicates water-bearing pipes on the ground floor running outside the wall. In bays 2(2), 5(5), 10(10) and 13(13), these pipes are located in rooms adjacent to the wall paintings. Violet indicates pipes and radiators on the first floor, directly above the vaults and wall paintings- specifically bays 2(2), 5(5), 10(10) and 13(13). The mapping is based on visible installations and on the historic heating plan from 1957 (Topení, podlaží 1 NP), as the installations are still in use. Modified by Rebecca Tehrani.

7.6 Micro-Climate Monitoring

Micro-climate monitoring was carried out in order to record the environmental conditions in the cloister and selected adjacent areas over an extended period of time. The monitoring focused on air temperature, relative humidity, dew point conditions and, where relevant, surface temperature in areas directly or indirectly related to the wall paintings of the Emmaus Cycle. The aim was to identify seasonal and spatial variations, assess the influence of heating and ventilation routines, and provide a data basis for the conservation assessment and future preventive conservation recommendations. The monitoring was conducted by TH Köln between July 2023 and March 2026 using a network of data loggers that continuously recorded interior and exterior air temperature, relative humidity and, at selected positions, surface temperature. In total, 21 monitoring devices were used: 19 sensors supplied by COMET Systems and two sensors supplied by Driesen + Kern (Figure 46, Figure 47). Additionally, two devices were installed by UPCE Team as a backup, placed in the same area as devices 007 and 012.

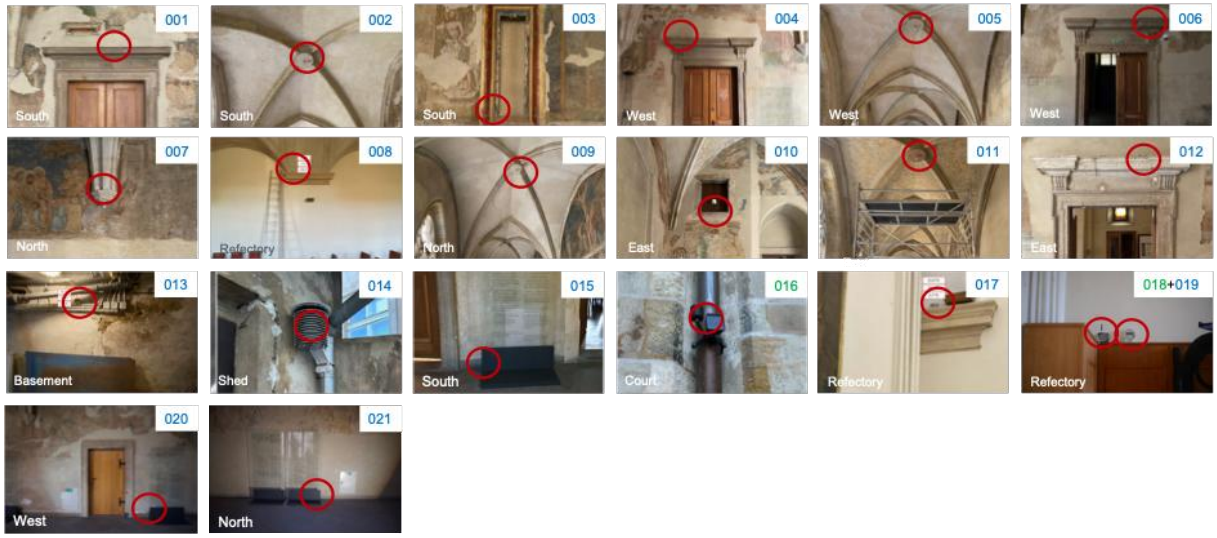


Figure 46: Location of 21 data loggers installed inside and outside the cloister. Blue numbers = loggers of the Comet System Model U3631M. Green numbers = Driesen & Kern devices, DBU- funded project AZ 38228/01. Images © Adrian Heritage and Rebecca Tehrani.

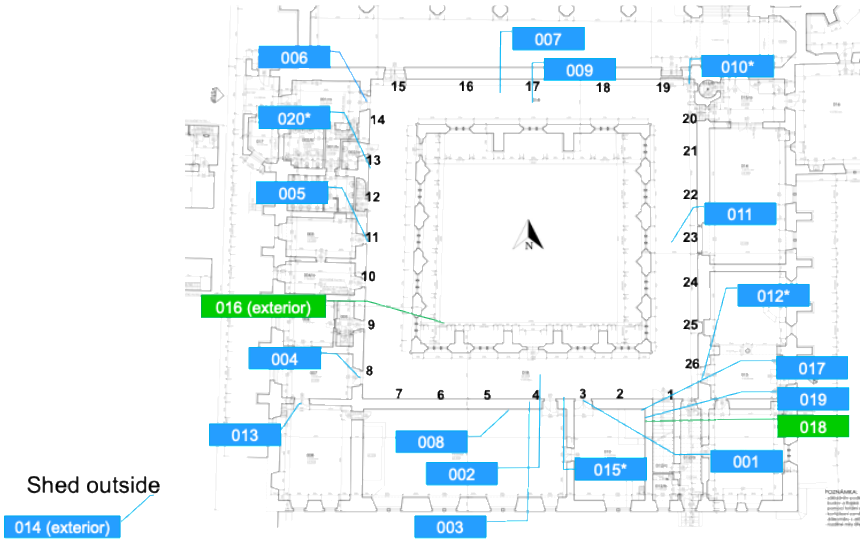


Figure 47: Floorplan C2.1 ©Archiprak –Projectová Kancelár M.G. Parma 2010, modified by RebeccaTehrani 2024. Location of 21 data loggers installed for micro-climate monitoring, DBU- funded project AZ 38228/01.

COMET System U3631M

Most of the monitoring was carried out with COMET System U3631M data loggers. These devices are equipped with an internal temperature and humidity sensor and record ambient air temperature [°C] and relative humidity [% RH]. The devices also calculate dew point temperature [°C]. According to the manufacturer's specifications, the measuring range for air temperature is –20 to +60 °C, with an accuracy of ±0.4 °C and a resolution of 0.1 °C. Relative humidity is measured within a range of 0 to 100 % RH, with an accuracy of ±1.8 % RH and a resolution of 0.1 %. The calculated dew point temperature range is –90 to +60 °C, with an accuracy of ±1.5 °C at ambient temperatures below 25 °C and relative humidity above 30 % RH. The COMET System U3631M loggers use SIM card technology, which allows the recorded environmental data to be uploaded to a cloud platform and accessed remotely. The recording interval for these devices was set to 30 minutes. Selected loggers (012_ULogger, 015_ULogger, 020_ULogger and 021_ULogger) were equipped with an external Pt100 temperature probe for measuring surface temperature [°C].

Driesen+ Kern two DK650 ruggedVisual

In addition, two DK650 ruggedVisual loggers supplied by Driesen + Kern were used. These devices are equipped with internal temperature and humidity sensors and record ambient air temperature [°C] and relative humidity [% RH]. According to the manufacturer's specifications, the measuring range for air temperature is –40 to +90 °C, with an accuracy of ±0.3 °C and a resolution of 0.01 K. Relative humidity is measured within a range of 0 to 100 % RH, with an accuracy of ±2 % RH and a resolution of 0.01 %. Dew point temperature is not calculated automatically by these devices. The recording interval for the Driesen + Kern loggers was set to 15 minutes. One of the DK650 ruggedVisual loggers was equipped with an RFT-325 humidity and temperature probe for outdoor installation.

7.6.1 Installation of the Devices

None of the monitoring devices was physically attached directly to the wall paintings. The data loggers were positioned in the cloister and selected adjacent spaces in a way that allowed relevant environmental conditions to be recorded while avoiding direct contact with the painted surfaces. Once installed, the individual sensor units were visually camouflaged in order to reduce their visual impact for users of the cloister. The external probes used for surface temperature measurements were also not attached directly to the wall paintings. Where surface temperature was measured close to painted areas, the probes were fixed only to nearby conservation plaster. For this purpose, Paraloid B72 with gauze, as well as Japanese tissue with Tylose MH 300, were used as reversible securing materials.

7.6.2 Location, Maintenance and Data Gaps

The COMET System U3631M loggers were distributed at different heights throughout the cloister and in selected adjacent rooms. The distribution of the devices was designed to capture spatial differences between the cloister walks and heights, as well as areas close to the wall paintings.

To contextualise the measurements with outdoor climate, one COMET System U3631M logger was installed outside the building on a water pipe and protected with a COMETEO Professional Thermometer Screen for Weather Station Sensors. One DK650 ruggedVisual logger was installed inside the cloister next to one of the COMET System loggers, allowing comparison between the two logger types. The second DK650 ruggedVisual logger was installed outdoors on a downpipe in the courtyard and protected by a self-made weather shield.

The installation of the loggers was mainly carried out in 2023 and 2024 with the support of students from TH Köln: Clara Camila Kolny, Karoline Reck, Ava Lina Scharffe and Chari-Juliane Tihanyi. Later adjustments, temporary dismantling for recharging, and repositioning of the devices were carried out by the TH Köln team together with project partners from UPCE and ABK Stuttgart. This was particularly important for positions at greater heights, where safe access required coordinated work on site.

As the monitoring devices were not all installed at the same time, the available recording periods differ between individual loggers. An overview of the recording periods for each device is provided in Figure 48. Temporary interruptions within these recording periods are listed separately in Table 6. During the initial recording phase, battery-related problems caused temporary interruptions in the measurements of several COMET System U3631M loggers. Further interruptions were related to the missing allocation of annual digital activation credits for the online COMET service to individual devices. These interruptions are visible in the monitoring graphs and were taken into account during the evaluation of the data.

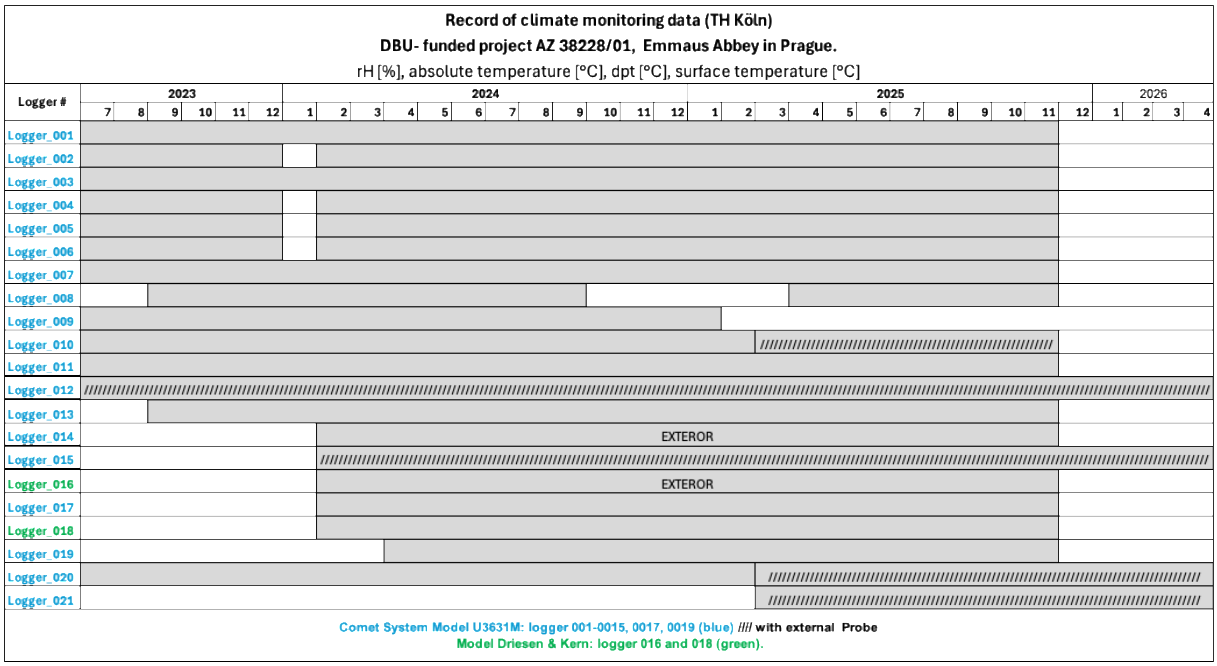


Figure 48: Overview of logger recording periods, DBU- funded project AZ 38228/01.

Due to these interruptions, as well as interruptions related to recharging the loggers for 24-48 hours, the monitoring data should not be understood as a fully uninterrupted record for every individual logger. However, the overall monitoring network remained sufficiently extensive to identify broader seasonal trends, spatial differences and relevant environmental patterns within the cloister and adjacent areas. The gaps are therefore considered a limitation for the interpretation of individual logger records, but they do not invalidate the general evaluation of the micro-climatic conditions

Table 6: Recorded data gaps in the COMET System U3631M monitoring dataset, DBU- funded project AZ 38228/01.

Logger	Data gap	Reason
002_ULogger	29.12.2023, 16:30 – 26.01.2024, 17:46	battery failure
003_ULogger	26.01.2024, 10:30–18:00	battery failure
004_ULogger	08.01.2024 – 27.01.2024	battery failure
005_ULogger	01.01.2024, 09:30 – 26.01.2024, 15:00	battery failure
006_ULogger	27.12.2023, 16:30 – 27.01.2024, 14:30	battery failure
007_ULogger	26.01.2024, 09:30–18:30	battery failure
008_ULogger	26.01.2024, 13:00 – 29.01.2024, 09:30; 26.09.2024, 21:30 – 25.03.2025, 14:30	battery failure
009_ULogger	26.01.2024, 10:30 – 27.01.2024, 18:00	digital activation credits
010_ULogger	26.01.2024, 10:30–19:30	digital activation credits
020_ULogger	29.08.2025 – 17.11.2025	digital activation credits
021_ULogger	09.10.2025 – 17.11.2025	digital activation credits

7.6.3 Reading and Data analysis

All raw data were downloaded from the monitoring devices as *.csv files. For the COMET System U3631M loggers, the recorded data could also be viewed, exported and partly evaluated directly through the COMET cloud system. The cloud platform provides access to the measured values in real time, but also to historic data and allows data to be displayed in graphs and tables. It also offers system-based reporting functions, including reports for individual measured locations and devices, with graphs, aggregated values (Figure 50).

However, access to the COMET cloud system requires a user account and access rights to the respective devices. The cloud-based reports are therefore dependent on continued access to the system and are not openly accessible to all future users of the project documentation. For this reason, an additional documentation and evaluation workflow was established for the project. This workflow allowed the

exported raw datasets to be processed independently of the COMET cloud platform and made available to the project partners in reusable file formats.
For the COMET System U3631M loggers, dew point temperature was calculated automatically by the devices. For the Driesen + Kern system, dew point temperature was calculated manually using the following approximation:

$$Td = T - [(100 - RH) / 5]$$

where Td is the dew point temperature, T is the air temperature and RH is the relative humidity.

Based on the downloaded datasets, individual climate data reports were generated for each logger using a dedicated template developed for the Emmaus micro-climate monitoring. The reports were created with the Plotly open-source graphing library for Python, using a script written by data analyst David Riedel (Plotly Technologies Inc., Collaborative data science, Montréal, QC, 2015, https://plot.ly/).
Each climate data report contains information on the logger ID, monitoring position, recording period and measured parameters. Depending on the individual logger configuration, the reports include time-series graphs for air temperature, relative humidity, dew point temperature and, where applicable, surface temperature. In addition to the graphical representation of the recorded data, the project-specific reports include statistical summaries with minimum, maximum and mean values for each month per dataset (Figure 50). This extended reporting format was one reason for establishing a separate Plotly-based documentation workflow, as the COMET cloud system did not provide the required statistical tables in in its export functions.

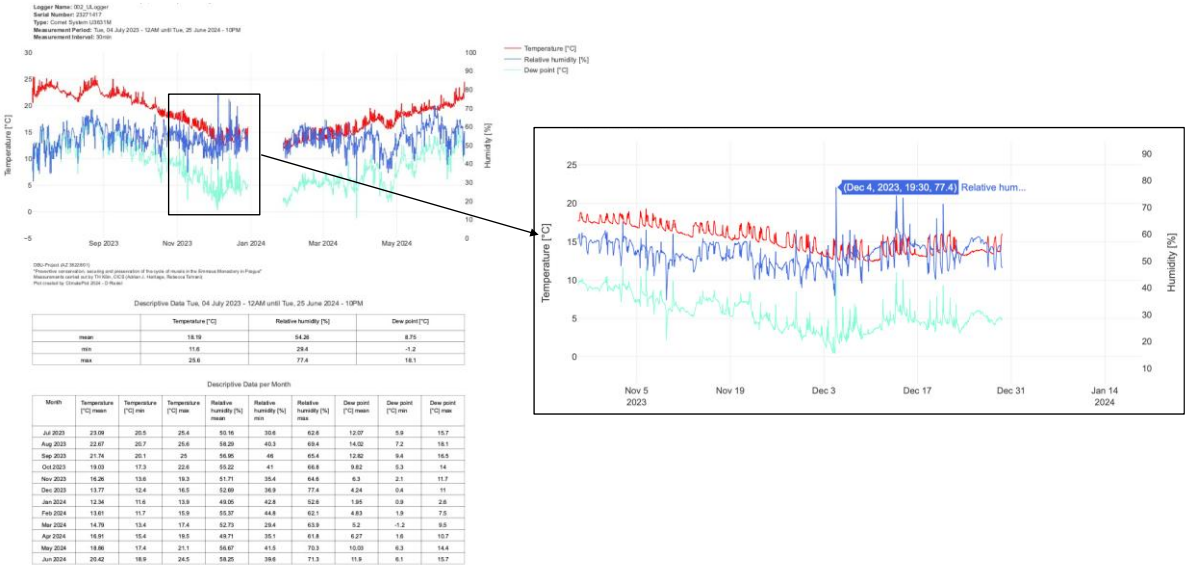


Figure 49 Example of a micro- climate data report for 002_ULogger, including a close-up of a selected area of interest. The report contains time-series data for the measured climate parameters, statistical summaries with minimum, maximum and mean values, and averaged views for selected time periods. Climate monitoring, Emmaus Abbey in Prague. Graph and table generated using the Plotly open-source graphing library for Python with a script written by data analyst (Plotly Technologies Inc., Collaborative data science, Montréal, QC, 2015, https://plot.ly/). Image © Rebecca Tehrani

The Plotly-based reports allow the graphs to be explored and adjusted according to the level of analysis required. In addition to the original measurement intervals, averaged values can be generated for selected time periods, for example for individual days, several-day periods, weeks or months. This makes it possible to smooth the graphs where necessary and to distinguish short-term fluctuations from broader seasonal trends. The original data remain available, while the averaged views support the interpretation of longer monitoring periods and the comparison between different logger positions.

The reports were exported as *.csv, *.svg, *.pdf and *.html files and uploaded to SharePoint and made accessible to all project partners. The *.html files allow the graphs to be explored interactively, for example by zooming in on specific time periods or by selecting and highlighting individual data series. Furthermore, the comparison of different data set is possible.

This format was chosen to provide a transparent, reproducible and reusable documentation of the monitoring results that can be consulted independently of access to the COMET cloud system. The climate data reports provided the basis for evaluating seasonal trends, short-term fluctuations, differences between individual monitoring positions and periods of particular relevance for the risk assessment.

7.6.4 Evaluation Approach and Relevance for Conservation Assessment

The micro-climate monitoring data provide a basis for assessing environmental conditions in the cloister and selected adjacent areas over an extended monitoring period. The monitoring results were used to support the risk assessment and the development of preventive conservation recommendations. A more detailed scientific interpretation of the complete dataset will be included in the final project publication. The data allow the identification of seasonal patterns in air temperature and relative humidity, the comparison of micro-climatic conditions between different cloister walks and adjacent spaces, and the assessment of short-term fluctuations related to heating, ventilation, building use or external weather conditions. Where surface temperature measurements were recorded, the data also support the evaluation of dew point-related conditions and possible condensation risks.

The monitoring data can be compared with the results of the visual condition assessment, the liquid moisture survey, the documentation of heating and service installations, and information on use, access and ventilation routines. In this way, the micro-climate monitoring contributes to a more differentiated understanding of potential environmental influences on the wall paintings and supported the ABC risk assessment.

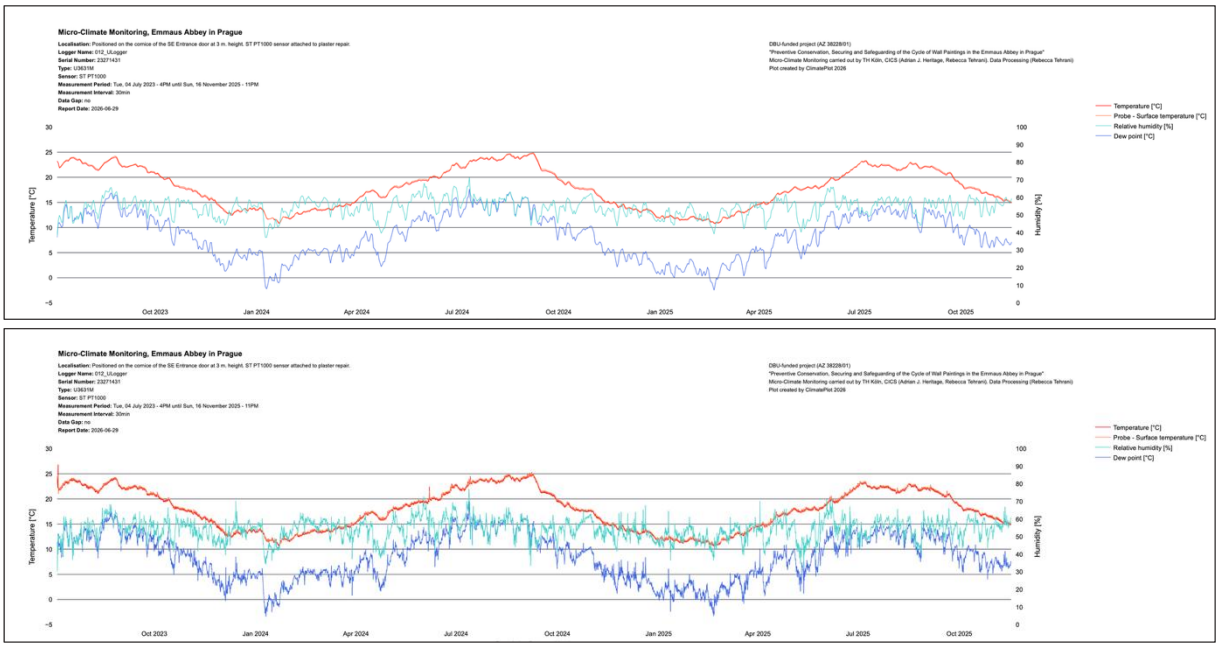
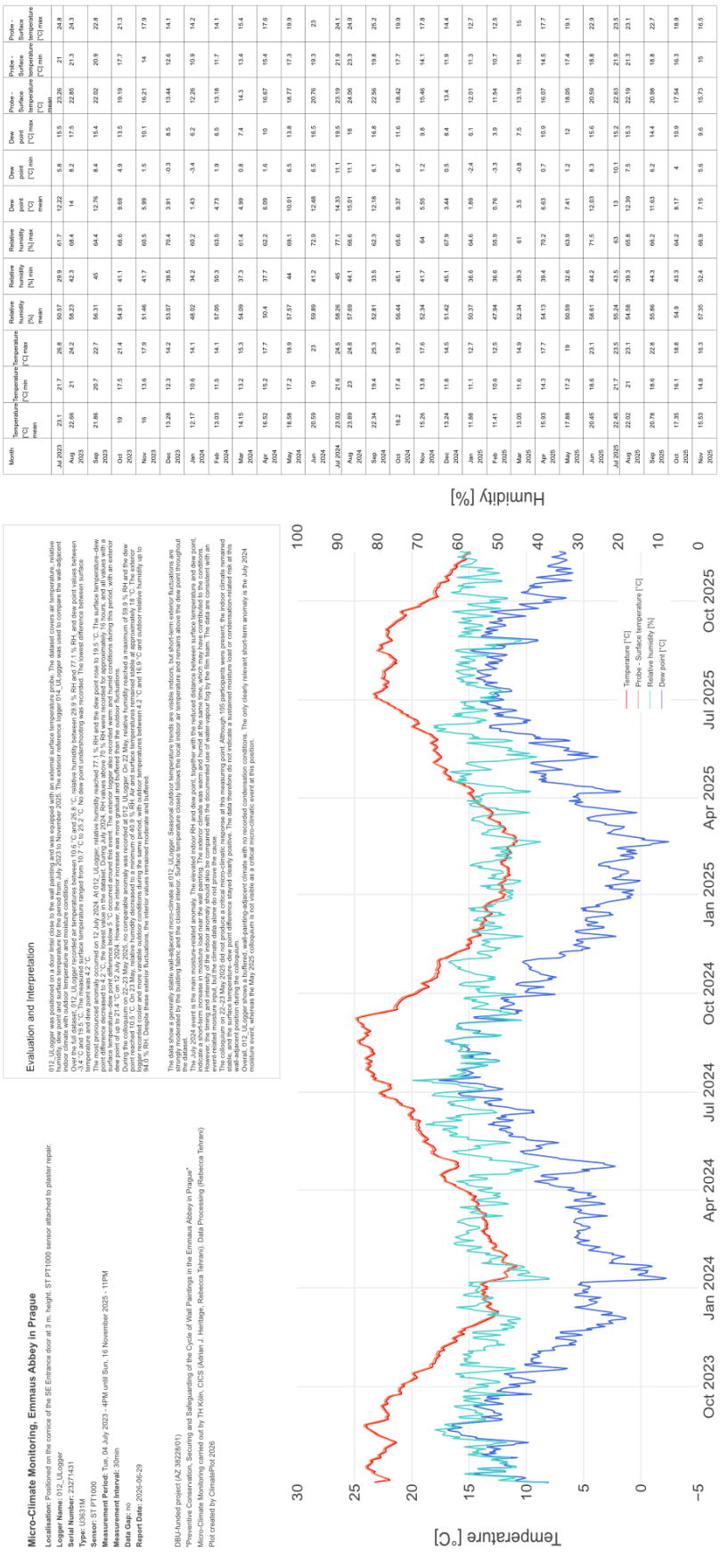


Figure 50: Example of a micro- climate data report for 012_Ulogger with recorded ambient temperature [°C], surface temperature [°C], relative humidity [%] and calculated dewpoint [°C]. Data collected between 07/2023 and 03/2026. The example shows difference between aggregated values per day (top) and all values measured every 30 minutes (bottom). Graph and table generated using the Plotly open-source graphing library for Python with a script written by data analyst (Plotly Technologies Inc., Collaborative data science, Montréal, QC, 2015, https://plot.ly/). Image © Rebecca Tehrani.



Month	Temperature [°C] mean	Temperature [°C] min	Temperature [°C] max	Relative humidity [%] mean	Relative humidity [%] min	Relative humidity [%] max	Dew point [°C] mean	Dew point [°C] min	Dew point [°C] max	Probe – Surface temperature [°C]	Probe – Surface temperature [°C] min	Probe – Surface temperature [°C] max
Jul 2023	23.1	21.7	26.8	50.57	28.9	61.7	12.22	5.8	15.5	23.26	21	24.8
Aug 2023	22.86	21	24.2	58.23	42.3	68.4	14	8.2	17.5	22.85	21.3	24.3
Sep 2023	21.86	20.7	22.7	56.31	45	64.4	12.76	8.4	15.4	22.02	20.9	22.8
Oct 2023	19	17.5	21.4	54.91	41.1	68.6	8.69	4.9	13.5	19.19	17.7	21.3
Nov 2023	16	13.6	17.9	51.46	41.7	60.5	5.99	1.5	10.1	16.21	14	17.9
Dec 2023	13.26	12.3	14.2	53.07	39.5	79.4	3.91	-0.3	8.5	13.44	12.6	14.1
Jan 2024	12.17	10.6	14.1	48.02	34.2	69.2	1.43	-3.4	6.2	12.25	10.9	14.2
Feb 2024	13.03	11.5	14.1	57.95	50.3	63.5	4.73	1.9	6.5	13.18	11.7	14.1
Mar 2024	14.15	13.2	15.3	54.09	37.3	61.4	4.99	0.8	7.4	14.3	13.4	15.4
Apr 2024	16.52	15.2	17.7	50.4	37.7	62.2	6.09	1.6	10	16.67	15.4	17.6
May 2024	18.58	17.2	19.9	57.57	44	69.1	10.01	6.5	13.8	18.77	17.3	19.9
Jun 2024	20.59	19	23	59.89	41.2	72.9	12.48	6.5	16.5	20.76	19.3	23
Jul 2024	23.02	21.6	24.5	58.26	45	77.1	14.33	11.1	19.5	23.19	21.9	24.1
Aug 2024	23.89	23	24.8	57.69	44.1	68.6	15.01	11.1	18	24.06	23.3	24.9
Sep 2024	22.34	19.4	25.3	52.81	33.5	62.3	12.18	6.1	16.8	22.56	19.8	25.2
Oct 2024	18.2	17.4	19.7	56.44	45.1	65.6	8.37	6.7	11.6	18.42	17.7	19.9
Nov 2024	15.26	13.8	17.6	52.34	41.7	64	5.55	1.2	9.8	15.46	14.1	17.8
Dec 2024	13.24	11.8	14.6	51.42	45.1	67.9	3.44	0.6	8.4	13.4	11.9	14.4
Jan 2025	11.88	11.1	12.7	50.37	36.6	64.6	1.89	-2.4	6.1	12.01	11.3	12.7
Feb 2025	11.41	10.6	12.5	47.94	36.6	55.9	0.76	-3.3	3.9	11.54	10.7	12.5
Mar 2025	13.05	11.6	14.9	52.34	39.3	61	3.5	-0.8	7.5	13.19	11.8	15
Apr 2025	15.93	14.3	17.7	54.13	39.4	76.2	6.63	0.7	10.9	16.07	14.5	17.7
May 2025	17.88	17.2	19	50.59	32.6	63.9	7.41	1.2	12	18.05	17.4	19.1
Jun 2025	20.45	18.6	23.1	58.61	44.2	71.5	12.03	8.3	15.6	20.59	18.8	22.9
Jul 2025	22.45	21.7	23.5	55.24	43.5	63	13	10.1	15.2	22.63	21.9	23.5
Aug 2025	22.02	21	23.1	54.58	39.3	65.8	12.39	7.5	15.3	22.19	21.3	23.1
Sep 2025	20.78	18.6	22.8	55.96	44.3	66.2	11.63	6.2	14.4	20.98	18.8	22.7
Oct 2025	17.35	16.1	18.8	54.9	43.3	64.2	8.17	4	10.9	17.54	16.3	16.9
Nov 2025	15.53	14.8	16.3	57.35	52.4	66.9	7.15	5.6	9.6	15.73	15	16.5

Figure 51: Figure 50: Example of a micro-climate data report for 012_Ulogger Data collected between 07/2023 and 03/2026. The report shows recorded ambient temperature [°C], surface temperature [°C], relative humidity [%] and calculated dewpoint [°C]. The report contains statistical summaries with minimum, maximum and mean values, and averaged views for selected time periods and a data description and interpretation. Graph and table generated using the Plotly open-source graphing library for Python with a script written by data analyst (Plotly Technologies Inc., Collaborative data science, Montréal, QC, 2015, https://plot.ly/). Interpretation and Image © Rebecca Tehrani.

7.7 Implementation of the ABC Method

The ABC Method is a value- and risk-based methodology that integrates the assessment of cultural significance with the identification and evaluation of risks affecting heritage assets. Its purpose is to identify the values associated with a heritage asset, assess the risks and deterioration processes that may threaten those values, and support the prioritisation of measures that reduce risk as effectively as possible within the available resources. Although the methodology has been developed primarily for museum collections, the present project explored and demonstrated its application to an in situ ensemble of medieval wall paintings within a historic monastic building, thereby providing a model for the assessment of comparable heritage sites.

Implementation of the methodology was supported by two ABC Risk Management workshops. The first workshop took place on-site at Emmaus Abbey on 16 January 2025, and the second was held online on 31 March 2025. Both workshops were moderated and documented by Dennis Mitschke M.A. The results were developed through collaborative discussions and participatory exercises, including mind mapping and risk-scenario assessment, involving the project partners and invited stakeholders. The workshops established the value framework, identified and evaluated the principal risks affecting the wall paintings, and contributed directly to the development of the recommendations and the Framework for Action presented in the final report.

7.7.1 ABC Workshop 1 - 2025-01-16

On January 16th, 2025, an internal ABC Risk Management Workshop was conducted at the Emmaus Abbey in Prague as part of the 4th on-site meeting of the DBU Project. The workshop aimed to establish the context for risk management, focusing on the Emmaus Cycle and its broader conservation challenges. The session brought together project partners, conservation specialists, abbey authorities, and stakeholders to systematically assess risks and align a framework for long-term preventive conservation.

The ABC Risk Management Workshop at the Emmaus Abbey followed a structured approach based on the ABC Risk Management Cycle. The session began with an overview of the methodology, outlining the key steps involved in risk assessment and conservation planning. The primary focus of this workshop was the first phase of the cycle—Building the Context—which served as the foundation for subsequent risk identification and mitigation strategies. To facilitate a comprehensive data collection process, participants worked within a predefined structure, systematically gathering information across multiple subtopics relevant to the conservation of the wall painting cycle. The following Context Categories were explored:

- Mission and Significance
- Actors and Stakeholders
- Political environment
- Physical environment
- Socio-cultural environment
- Legal aspects
- Financial context
- Administrative and operational aspects

As part of this process, the collected information was visualized using a mind map (Figure 53), allowing participants to better understand the interconnections between different aspects of risk management.

One of the central challenges that emerged during the discussion was the classification and definition of values attributed to the wall painting cycle in comparison to other parts of the building. The complexity of this issue became apparent as participants attempted to align the significance of the paintings within the broader context of the building. Finding a clear and structured approach to addressing this challenge remains an open task for future discussions.
Despite these conceptual difficulties, the workshop successfully compiled crucial information regarding responsibilities, legal and financial frameworks, environmental influences, and operational aspects related to the abbey.

Figure 52: Data collection during the first workshop. The data collection was conducted through a collaborative brainstorming session, during which key insights were actively discussed and refined. © Dennis Mitschke.

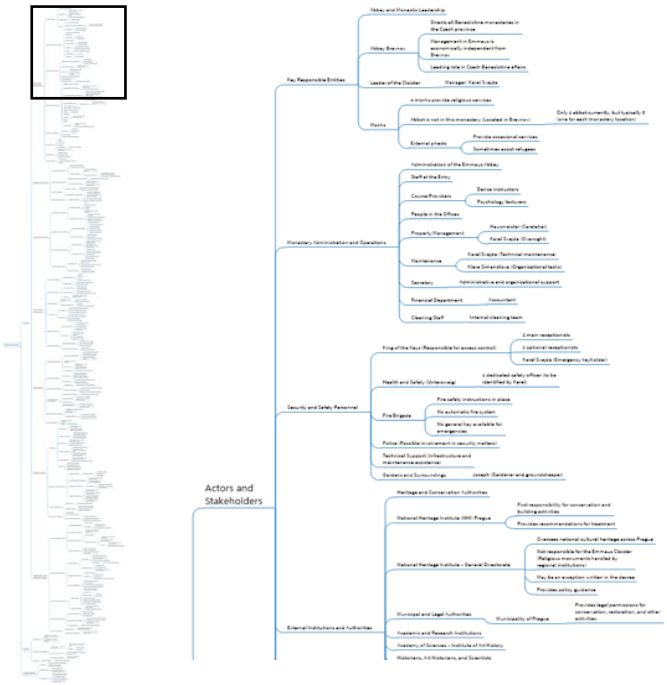


Figure 53: Mind map documenting all workshop results. © Dennis Mitschke.

7.7.2 Post-Workshop Results

Preliminary Mission Statement

The Emmaus Abbey is committed to preserving its historic, artistic, and spiritual heritage while maintaining its primary function as a living monastic space. The abbey's wall painting cycle is a cultural treasure of European significance, valued not only for its artistic excellence but also for its historical and identity-defining role.

Our mission is to ensure the careful conservation of these exceptional wall paintings while respecting the abbey's active religious life. We seek to balance accessibility and preservation, allow scholarly research and select public engagement without overwhelming the site's sacred and peaceful environment.

By maintaining a thoughtful and sustainable approach, we protect both the abbey's heritage and the daily life of its community. We remain dedicated to fostering historical awareness, cultural appreciation, and responsible stewardship of this unique site for future generations.

Preliminary Significance Statement

The wall paintings of the Emmaus Abbey represent an outstanding artistic and historical treasure of Middle Europe. Created by top-tier painters, they form one of the most significant surviving wall painting cycles in the region, showcasing exceptional craftsmanship and artistic quality.

Beyond their artistic value, these paintings hold profound historical and cultural significance. Their connection to Charles IV situates them within a broader European context, reflecting the political and religious dynamics of their time. As one of the few remaining monumental painting cycles of its kind, they contribute to the identity and heritage of Prague, extending their influence beyond national borders and resonating with artistic traditions in Warsaw and across Europe.

The abbey itself is not just a historical monument but a living religious space, where the balance between conservation, public access, and monastic life must be carefully maintained. While the paintings are of great value to art history, the abbey prioritises preserving its quiet spiritual atmosphere, limiting tourism to protect both the site and its function.

7.7.3 Conclusion

The ABC Risk Management Workshop at the Emmaus Abbey provided valuable insights into the current state of preservation, administrative responsibilities, financial constraints, and risk factors affecting the wall painting cycle. Through structured discussions and a collaborative mind-mapping session, participants gathered and categorised critical data related to the conservation context.

One of the most significant challenges that emerged during the workshop was the attribution of value to the wall painting cycle in comparison to other parts of the building. Defining its hierarchical importance within the broader heritage structure proved complex, as different stakeholders brought a variety of perspectives on its cultural and spiritual significance. More importantly, the method employed to assess the relative value of the various components was perceived as problematic, as it involved assigning values to parts of the building and surroundings. Addressing this challenge requires further dialogue and consensus-building among conservation experts, abbey authorities, and heritage institutions.

Financial constraints also emerged as a central concern. While the abbey is capable of funding minor conservation treatments, larger interventions depend on external funding from the municipality, state, or European grants. However, participants highlighted that available funding mechanisms often fail to address medium-scale conservation projects, leaving a significant gap between small-scale maintenance efforts and large-scale restorations.

From an administrative perspective, the workshop clarified the roles and responsibilities of various stakeholders (Figure 54), including the National Heritage Institute (NHI), the Ministry of Culture, the Municipality of Prague, and the Benedictine Order. Although the abbey formally owns the building, its ability to independently manage conservation projects is limited due to legal constraints and regulatory requirements. Navigating these bureaucratic structures and securing the necessary permissions for restoration work remains an ongoing challenge.

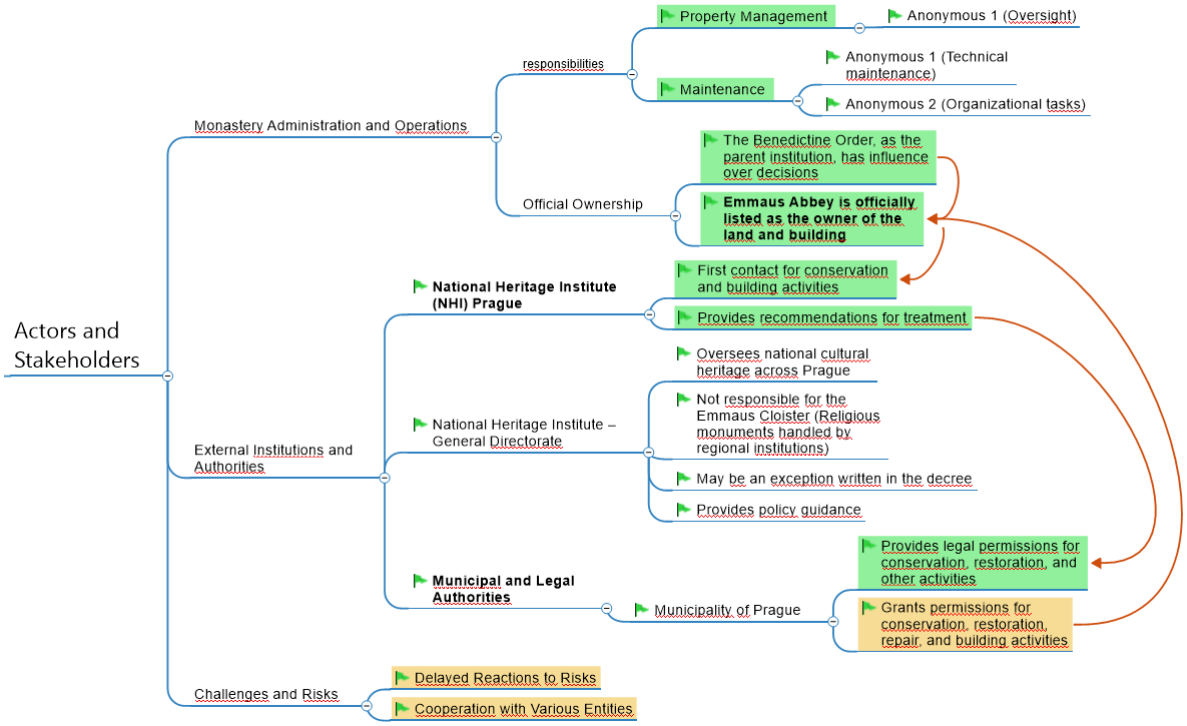


Figure 54: Roles of key Actors and Stakeholders. ©Dennis Mitschke.

Additionally, concerns were raised regarding fire protection, emergency preparedness, and maintenance procedures. While the fire alarm system is regularly checked, gaps remain in fire prevention measures, staff training, and long-term conservation planning. Despite these challenges, the workshop successfully established a solid foundation for the subsequent phases of the risk management process. The collected data serves as a comprehensive reference for identifying risks, prioritising conservation needs and developing strategies for long-term preservation.

7.8 Workshop 2 - 2025-03-31

Building on the foundation and contextual understanding developed during the first ABC Risk Management Workshop, the second workshop focused on the next phase of the risk management cycle: the identification and analysis of risks affecting the wall painting cycle at the Emmaus Abbey. To improve efficiency and avoid starting from scratch, the team utilized the pre-established “SILK Scenarios” as a baseline. These scenarios provided a structured starting point to which site-specific risks at the Emmaus Abbey were added and adapted. The following people attended the online workshop:

Projekt partners: Daniela Jukubu, UPCE (DJ); Roland Lenz, ABK Stuttgart (RL); Petra Lesniaková, UPCE (PL); Dennis Mitschke TH Köln (DM); Katharina Schellbach, ABK Stuttgart (KS); Rebecca Tehrani, TH Köln (RT); Jan Vojtěchovský, UPCE (JV); Judit Zöldföldi ABK Stuttgart (JZ).
External workshop participants: Petra Hoftichová, NPU Praha (PH)

7.8.1 Developing a Common Risk Scale

To ensure consistent communication and interpretation of risk severity among all participants, the workshop began with the development of a shared damage scale. This scale ranged from 1 (minimal loss) to 5 (total loss of value) and served as a reference for later analysis.

To initiate this process, a series of visualised damage scenarios was presented in random order on a whiteboard (Figure 55). Participants were asked to collectively sort these scenarios according to the ICCROM B-Score-scale (Figure 56 and Figure 57). The moderator adopted a neutral role, intervening only to ask clarifying questions, thereby encouraging active dialogue and consensus-building among participants.

Figure 55: Random risk scenarios to be arranged Collage © Dennis Mitschke.

B-Score	Fraction of value lost in each affected item	Word guidelines
5	100 %	**Total or almost total loss** of value in each affected item
4 ½	30 %	
4	10 %	**Large** loss of value in each affected item
3 ½	3 %	
3	1 %	**Small** loss of value in each affected item
2 ½	0.3 %	
2	0.1 %	**Tiny** loss of value in each affected item
1 ½	0.03 %	
1	0.01%	**Trace** loss of value in each affected item
½	0.003 %	

Figure 56: B-Score - Extent of damage scale, Pedersoli Jr., Antomarchi, Michalski (2016): ICCROM Guide to Risk Management p.65

Figure 57: Scale of damage – Agreed by project team. Collage © Dennis Mitschke.

This exercise was crucial for establishing a common language and aligning understanding across a multidisciplinary group, laying the groundwork for the evaluation of additional risk scenarios.

7.8.2 Risk Identification and Example Scenarios

Following the scale exercise, participants were introduced to the next steps of the ABC risk analysis procedure. This involved assessing two key factors for each risk scenario: (A) the frequency or probability of occurrence and (B) the extent of potential damage. To introduce these concepts, a visual overview of the previously identified risk factors was presented in the form of a second mind map (Figure 58 and Figure 59), allowing participants to contextualize the risks in relation to the Emmaus Abbey site.

Given the limited time available during the session, the team focused on two representative risk categories, fire and violence, to demonstrate the assessment method in practice. Using a real-time Mentimeter survey, participants were invited to submit their evaluations, which were then visualized and discussed collaboratively (Figure 60). This interactive approach fostered shared understanding and prompted a valuable discussion on how risk manifests locally.

Based on this initial demonstration, the group collectively agreed that a more comprehensive risk assessment should be carried out using a structured online questionnaire. This tool would be distributed to all project partners and stakeholders, allowing for asynchronous, in-depth assessment of each scenario using the A/B scoring system. The goal was to ensure consistent, comparable data collection across the full range of locally relevant risks.

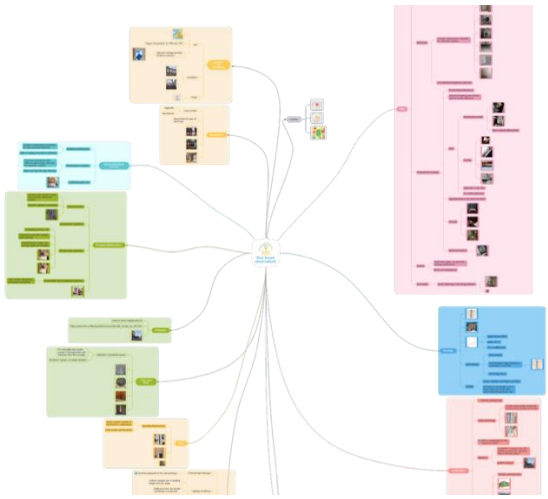


Figure 58: Mind map: Data collection for risk categories © Dennis Mitschke.

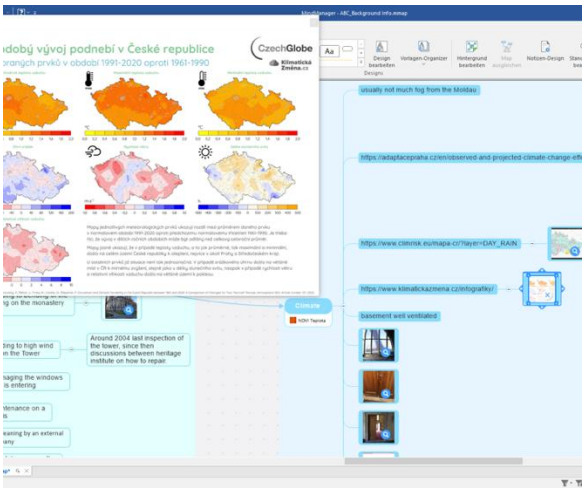


Figure 59: Detail of Mind map: Data collection for risk categories © Dennis Mitschke.

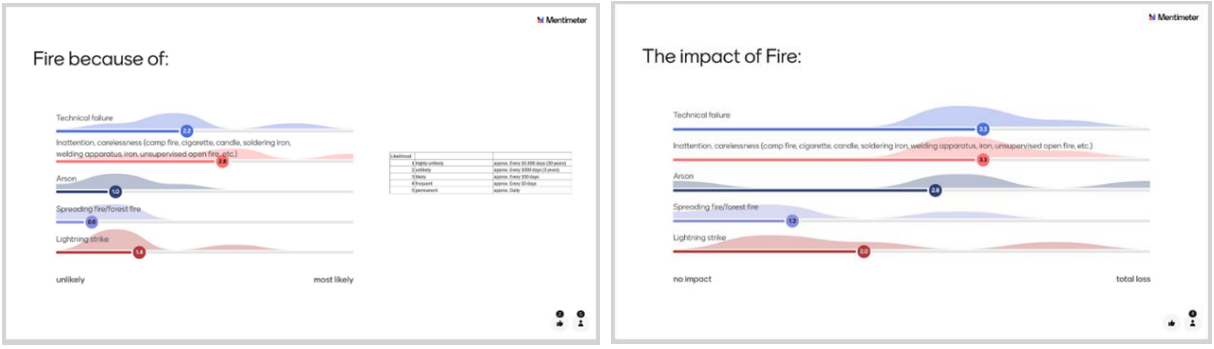


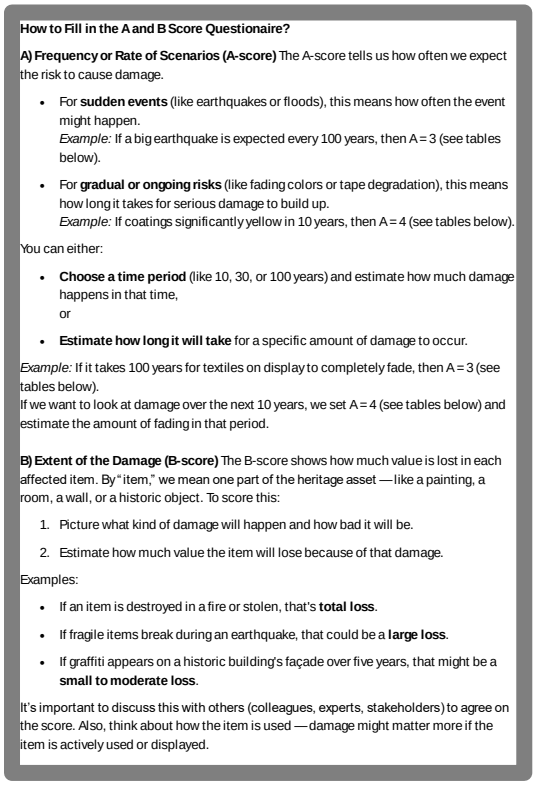
Figure 60: Mentimeter result © Dennis Mitschke.

7.8.3 Questionnaire and Data processing

The questionnaire was designed to gather individual assessments of each of the 51 identified risk scenarios, using the shared damage scale as reference. Instructions were provided to ensure a standardized approach to evaluation across all participants.

Once submitted, the questionnaire data was exported into an Excel spreadsheet, where the responses were automatically processed to calculate minimum, maximum, and average scores for each risk category. This statistical data was then transferred into the ABC Risk Management Database tool, enabling visualization, comparison, and prioritization of the risks.

Participants were also invited to include comments explaining their reasoning, thereby contextualizing each assessment and anchoring it in the specific conditions of the Emmaus Abbey.



How to Fill in the A and B Score Questionaire?

A) Frequency or Rate of Scenarios (A-score) The A-score tells us how often we expect the risk to cause damage.

- For **sudden events** (like earthquakes or floods), this means how often the event might happen.
  Example: If a big earthquake is expected every 100 years, then A = 3 (see tables below).
- For **gradual or ongoing risks** (like fading colors or tape degradation), this means how long it takes for serious damage to build up.
  Example: If coatings significantly yellow in 10 years, then A = 4 (see tables below).

You can either:

- **Choose a time period** (like 10, 30, or 100 years) and estimate how much damage happens in that time,
  or
- **Estimate how long it will take** for a specific amount of damage to occur.

Example: If it takes 100 years for textiles on display to completely fade, then A = 3 (see tables below).
If we want to look at damage over the next 10 years, we set A = 4 (see tables below) and estimate the amount of fading in that period.

B) Extent of the Damage (B-score) The B-score shows how much value is lost in each affected item. By "item," we mean one part of the heritage asset — like a painting, a room, a wall, or a historic object. To score this:

1. Picture what kind of damage will happen and how bad it will be.
2. Estimate how much value the item will lose because of that damage.

Examples:

- If an item is destroyed in a fire or stolen, that's **total loss**.
- If fragile items break during an earthquake, that could be a **large loss**.
- If graffiti appears on a historic building's façade over five years, that might be a **small to moderate loss**.

It's important to discuss this with others (colleagues, experts, stakeholders) to agree on the score. Also, think about how the item is used — damage might matter more if the item is actively used or displayed.

Figure 61: Questionnaire instructions © Dennis Mitschke.

7.8.4 Key Findings from the Risk Assessment Questionnaire

The aggregated results from the distributed questionnaire revealed a clear prioritisation based on the magnitude of risk on the wall painting cycle at the Emmaus Abbey (Figure 61). Participants rated risks on a standardised damage scale, enabling comparative analysis across diverse risk categories.

The highest-risk scenarios, based on the calculated average magnitude, centred around fire-related threats, with the most significant concern attributed to:

- Fire caused by inattention or carelessness, such as open flames, cigarettes, candles, or construction tools.
- Fire resulting from technical failure, including electrical malfunctions and overheated systems.
- The consequences of fire extinguishing water, which was recognised as a secondary but highly damaging risk.

In addition to fire, structural risks—such as building failure (e.g., roof collapse)—also ranked among the top concerns, highlighting vulnerabilities in the abbey's physical integrity.

Other significant risks identified include:

- Deterioration from environmental influences, particularly yellowed coatings, temperature fluctuations, and elevated temperatures caused by visitor presence, which can accelerate degradation of sensitive wall painting surfaces.
- Weather-related risks such as lightning, hail, and heavy or continuous rain were flagged due to their potential to cause both direct and indirect damage.
- Material-based deterioration through salt efflorescence was also noted as a recurring issue.

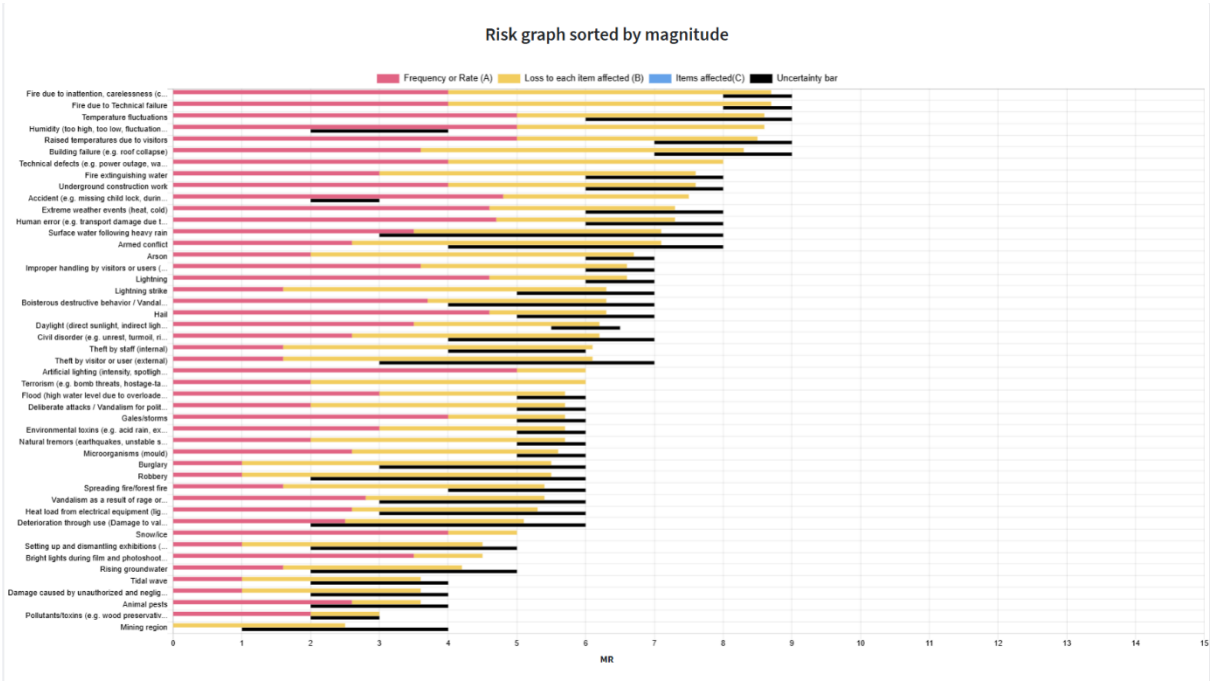


Figure 62: Questionnaire results visualized with the ABC-Database-Tool. Evaluation created by Dennis Mitschke.

Technical issues, including water pipe failures, power outages, and system malfunctions, were identified as potentially disruptive, particularly in relation to local water leaks.

These findings underscore the need for an integrated preventive strategy that addresses both high-magnitude catastrophic events (e.g., fire or collapse) and more subtle, cumulative risks (e.g., coatings, salts, and environmental stressors). The data served as a foundational reference for risk prioritisation and development of targeted mitigation measures.

7.8.5 Presentation at the International Colloquium

The methodology and results of this second workshop were presented during the opening day of the three-day International Colloquium on Mural Preservation (May 22–24, 2025), held under the theme: "Looking at Risks – Applying the ABC Risk Management Method to the Emmaus Painting Cycle."

This presentation not only showcased the practical application of the method but also stimulated broader dialogue on risk-based decision-making in the conservation of historic wall painting cycles in active religious heritage sites.

8 WP7: Material Analysis with Invasive Analytical Methods

→ Corresponding chapters in the final report: Chapter 2.8 Material Analysis with Invasive Analytical Methods (WP7), Chapter 3.1 Conservation History and Restoration Campaigns, Chapter 3.2 Painting Technique and Materials, Chapter 3.3 Current Condition and Deterioration Phenomena

8.1 Methodology

Laboratory investigation of micro-samples originating from the cycle of medieval wall painting in the cloister of the Emmaus Abbey in Prague was conducted in close interdisciplinary cooperation and systematically followed an extensive non-invasive survey. This coordinated approach enabled more targeted sampling while reducing the number of micro-samples taken, in accordance with the principal objective of the investigation to minimise intervention in the paintings.

The sampling was mostly performed by restorers Daniela Jakubů and Jan Vojtěchovský from UPCE team. The survey was carried out by Petra Lesniaková from the UPCE team. Some analyses were carried out in cooperation of external experts, namely by Václav Pitthard, Ladislav Lapčák, Miroslava Trchová, Ivana Kopecká and Lucie Poláková as further mentioned in the text.

The sampling locations were documented photographically in detail using a ColorChecker Classic Nano chart (*X-Rite*), by macrophotography, and were also annotated on photogrammetric images (Figure 63). To minimise invasiveness, micro-samples were preferentially taken from already damaged areas of the paintings such as at borders of fills or cracks. Each sampling location was further analysed using a handheld X-ray fluorescence spectroscopy (pXRF; Vanta VMR *Olympus*) to inform the interpretation of earlier point measurements.

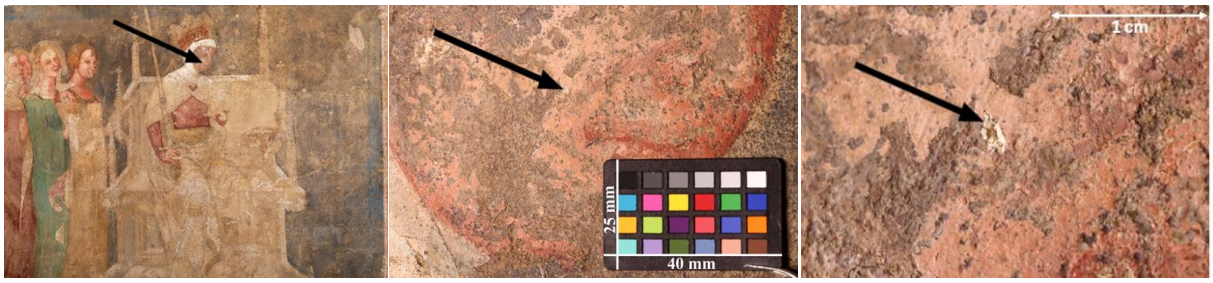


Figure 63: Photographic documentation and localisation of sampling: Judith's face, scene Judith with the Head of Holofernes, Bay 5(5), from the left: location of sampling pointed in a photogrammetric image (©Jiří Vidman); detail with a reference colour chart which also serves as a scale (©Vojtěchovský, Jakubů, Lesniaková); macrophotography with a scale (©Jan Vojtěchovský, Daniela Jakubů, Petra Lesniaková).

In total 35 micro-samples were examined and documented by optical microscopy (OM, Eclipse LV100D-U *Nikon*) in visible light (VIS), ultraviolet-induced visible luminescence (UVL), and blue light-induced visible luminescence (VISL). Suitable fragments of samples were selected for the preparation of cross-sections which all have been examined using optical microscopy (OM, Eclipse LV100D-U *Nikon*) employing the same techniques as described above and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM–EDX, Mira 3 LMU *Tescan*). Both point measurements as well as area element analyses were performed by SEM-EDX on all cross sections. Examples of the analytical methodology are present below (Figure 64, Figure 65, Figure 66).

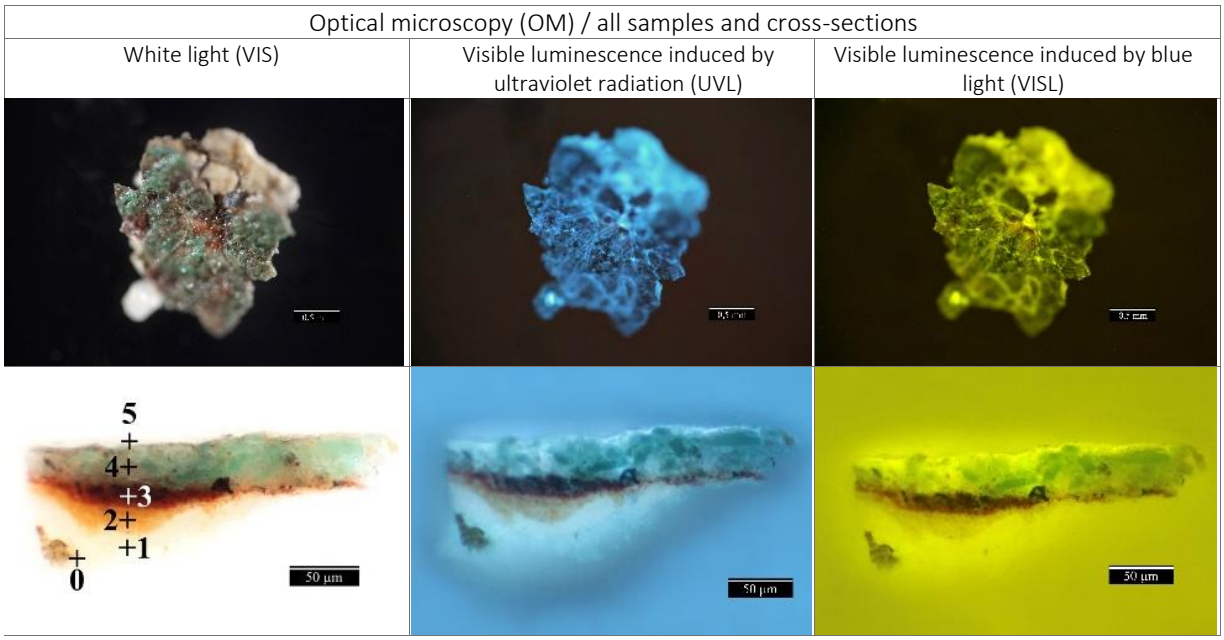


Figure 64: Example of sample processing by OM – micro-images of compact sample and its cross-section (VIS, UVL, VISL) and the overall stratigraphy of wall paintings (see 2.7.2 Techniques of the Historical Paintings and Gilding) described on cross-section in visible/white light (VIS). ©Petra Lesniaková.

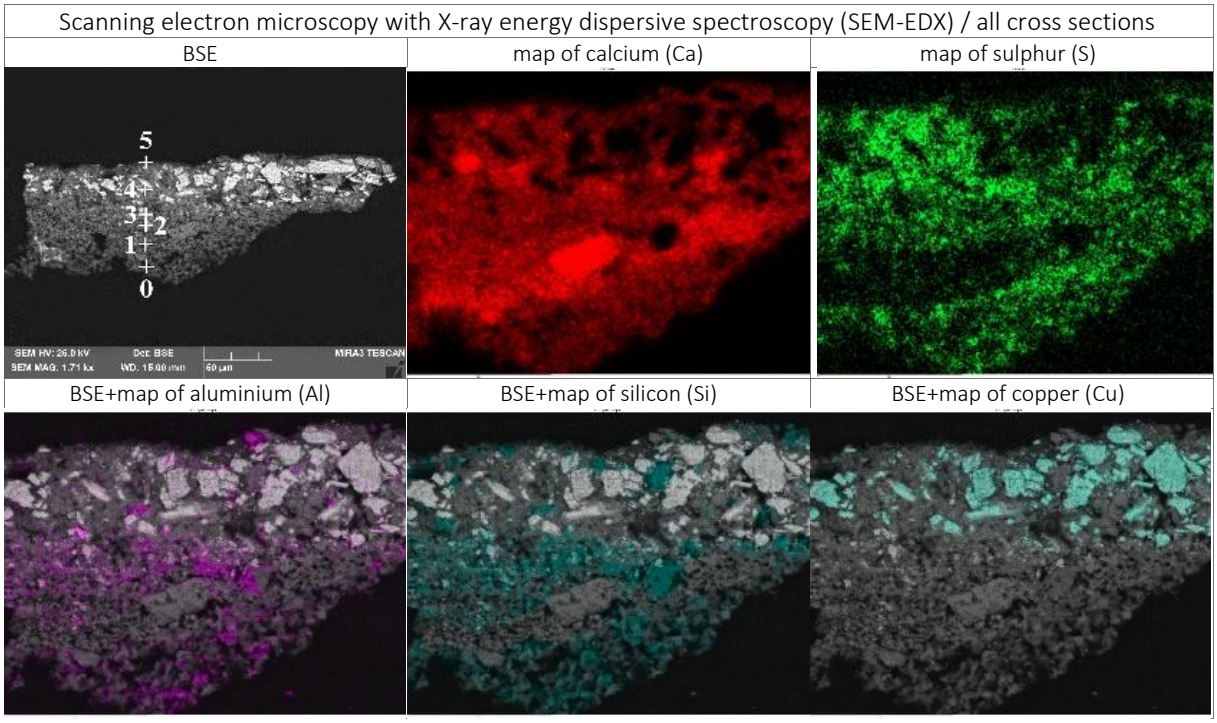


Figure 65: Example of investigation of samples by SEM-EDX (BSE – back scattered electrons, stratigraphy, element mapping). ©Petra Lesniaková.

For further identification of pigments selected cross-sections were subsequently analysed by Raman microspectroscopy (µRS, DXR2 *Thermo Scientific*). Selected fragments of micro-samples were further analysed by Fourier transformed infrared microspectroscopy (µFTIR, Nicolet iN10mx/ATR Ge *Thermo Scientific* or RaptIR/ATR Ge *Nicole*t) with the aim to identify transparent superficial coatings. These analyses were performed by external experts Ladislav Lapčák and Miroslava Trchová from University of Chemistry and Technology Prague or Ivana Kopecká and Lucie Poláková from National Technical Museum Prague (Figure 66).

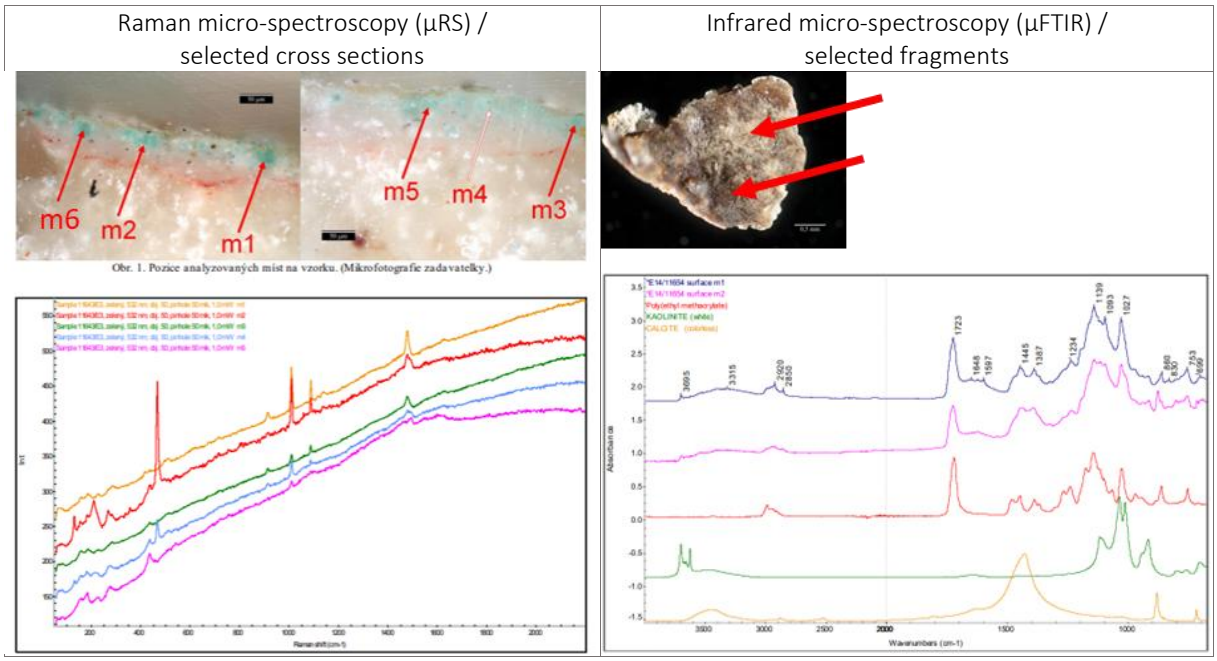


Figure 66: Example of using µRS on cross sections (on the left) and µFTIR on fragments of micro samples (on the right). ©Petra Lesniaková.

8.2 Techniques of the Historical Paintings and Gilding

The general stratigraphy of the original paintings comprises locally applied white chalk grounds, an ochre imprimatura, followed by brush underdrawings, local underpainting, and the final paint layers. The micro-images of cross sections (Figure 65) show the general stratigraphy of the painting including: 0) intonaco – white aerial lime with silicate aggregates; 1) chalk ground – natural chalk and organic binder; 2) ochre imprimatura – earth pigments; 3) red underpaintings – earth pigments, charcoal black, calcium carbonate; 4) paint layer – malachite, calcium carbonate, gypsum; 5) additions. The black underpainting (*veneda*) which is not shown here was executed under the blue backgrounds.

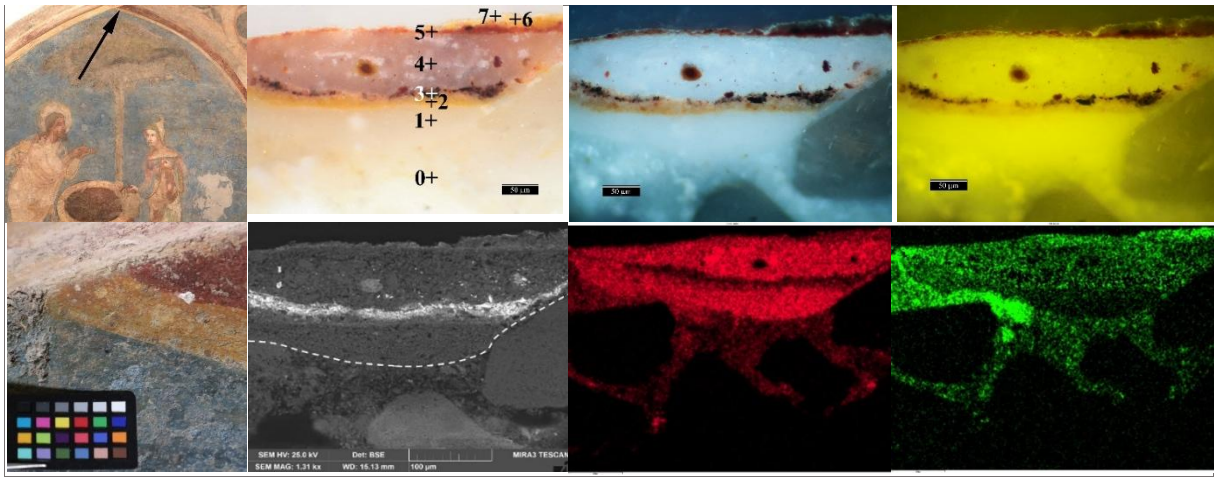


Figure 67: Example of painting executed on a chalk ground: yellow architectural painting, scene Jesus and the Woman of Samaria, Bay 18(20+21): sampling location, photogrammetry (©Jiří Vidman), detail (©Vojtěchovský, Jakubů, Lesniaková); cross-section, OM–VIS, OM–UVL, OM–VISL ©Petra Lesniaková 0) intonaco, 1) chalk ground, 2) yellow imprimatura, 3–6) paint layers, 7) organic coating with intense white–blue UV luminescence; cross-section, SEM–BSE and element maps of calcium/red and sulphur/green ©Petra Lesniaková.

As noted above, the chalk grounds (Figure 67) were applied directly onto the intonaco. Although they appear to have been intended primarily to unify, level, and smooth the surface, they generally form only

a thin layer. They consist of natural chalk and an organic binder. Reliable differentiation from the intonaco required SEM–EDX analysis, which non-destructively confirmed the presence of chalk and indicated an organic, rather than lime-based, binder. In some cases, the chalk ground could only be identified based on the elemental mapping (SEM–EDX). Although chalk grounds proved more widespread than previously assumed, their presence cannot yet be clearly defined across all painted bays.

Gas chromatography–mass spectrometry (GC–MS, 6890N gas chromatograph connected to a quadrupole mass spectrometer, model 5973N, both *Agilent Technologies*) was applied to four additional powdered samples to identify natural organic binders by V. Pitthard at Kunsthistorisches Museum Wien. GC–MS analyses revealed binders based on whole egg, with the additional polysaccharides and, probably, drying oils (Figure 68). These results suggest the use of an egg tempera technique, or possibly fatty egg tempera. The polysaccharides are more likely to represent additives or contamination. Table 6 illustrates examples of locations of sampling (paintings of blue draperies) and results of GC-MS analyses as well as the differences in paintings structure/stratigraphy on micro-images of cross-sections.

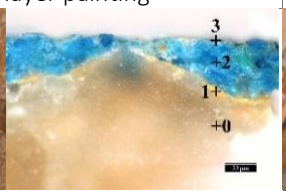
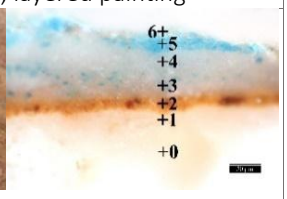
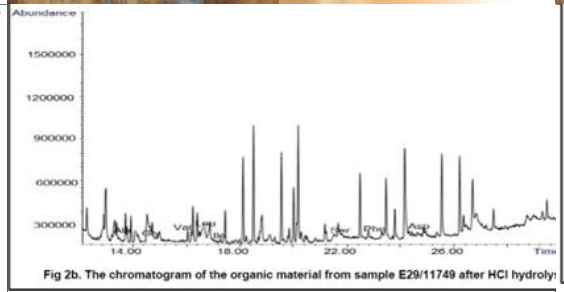
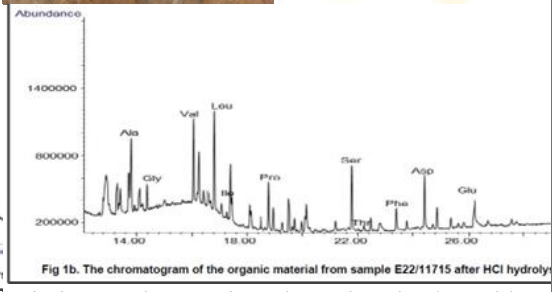
scene/bay /sample	The Ascension, drapery of Virgin Mary, Bay 25(32), single-layer painting	The Adoration of the Magi, drapery of Virgin Mary, Bay 10(10), layered painting
sampling point	 	 
results of GC-MS analyses	 Fig 2b. The chromatogram of the organic material from sample E29/11749 after HCl hydroly	 Fig 1b. The chromatogram of the organic material from sample E22/11715 after HCl hydroly
	whole egg, drying oils, polysaccharides (possibly starch, dextrin, or cellulose)	whole egg, drying oils, polysaccharides (possibly plant gums, starch, dextrin, cellulose, sugar, or honey), phthalates

Figure 68: Examples of GC-MS analyses (©Václav Pitthard) on two samples taken from blue draperies of Virgin Mary with relevant locations (©Jiří Vidman) and painting stratigraphy OM–VIS (©Petra Lesniaková) from the same locations.

In addition to the wall paintings, the decoration of bays also includes several types of gilding techniques. Detailed laboratory investigation focused on the technology of the relief gilding of halos and angels' wings which can be found in Bays 1(1) and 3(3). It was found that the relief parts were made using tin relief patterns covered with gold leaf (Figure 69), which further confirms the high level of technical expertise. The tin foil ranges from approximately 10 to 40 µm in thickness; in some areas, it has blackened due to degradation and locally lost adhesion to the fill. GC–MS analyses showed that the brown–ochre fill beneath the tin foil is bound with a mixture of linseed oil and resin (rosin) with a polysaccharide additive (probably starch or dextrin).

8.3 Materials of Later Interventions

The investigation aimed not only to identify the materials and techniques of the original paintings, but also to detect and analyse the remnants of added materials. These include fills, retouching, overpainting, and synthetic fixative coatings, often present in multiple layers.

Figure 70 shows the most prominent overpainting represented by a thick, glossy red layer, the presence of which can already be recognised in many areas of the painting cycle by visual inspection. The overpaint is modelled in two layers of similar composition, comprising red earth pigment, calcium carbonate and calcium sulphate dihydrate.

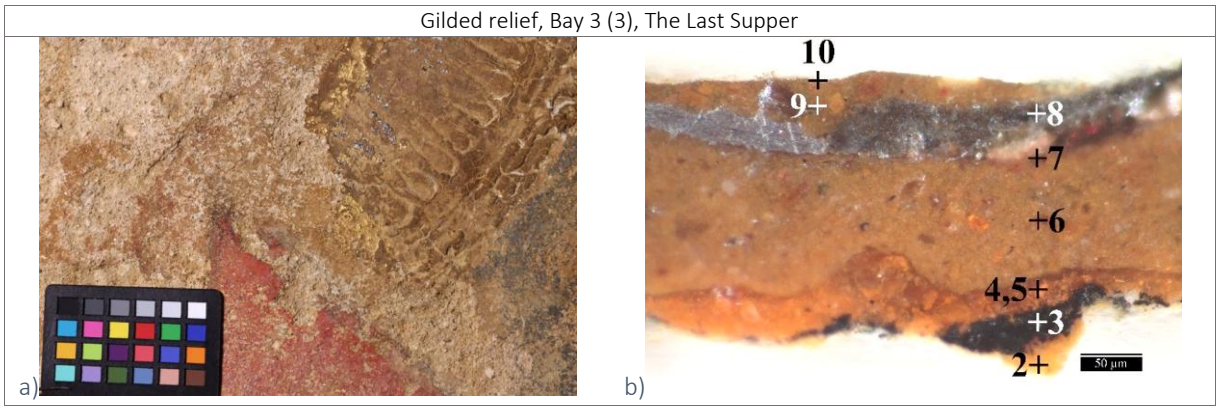


Figure 69a-b: a) Detail of relief gilded halo, (©Jan Vojtěchovský, Daniela Jakubů, Petra Lesniaková); b) examples of stratigraphy of tin gilded relief on cross-section OM–VIS, the tin foil (layer 8) was filled by ochre material (layer 6, 7), on the tin foil the ochre ground (layer 9) and gold leaf were applied. ©Petra Lesniaková.

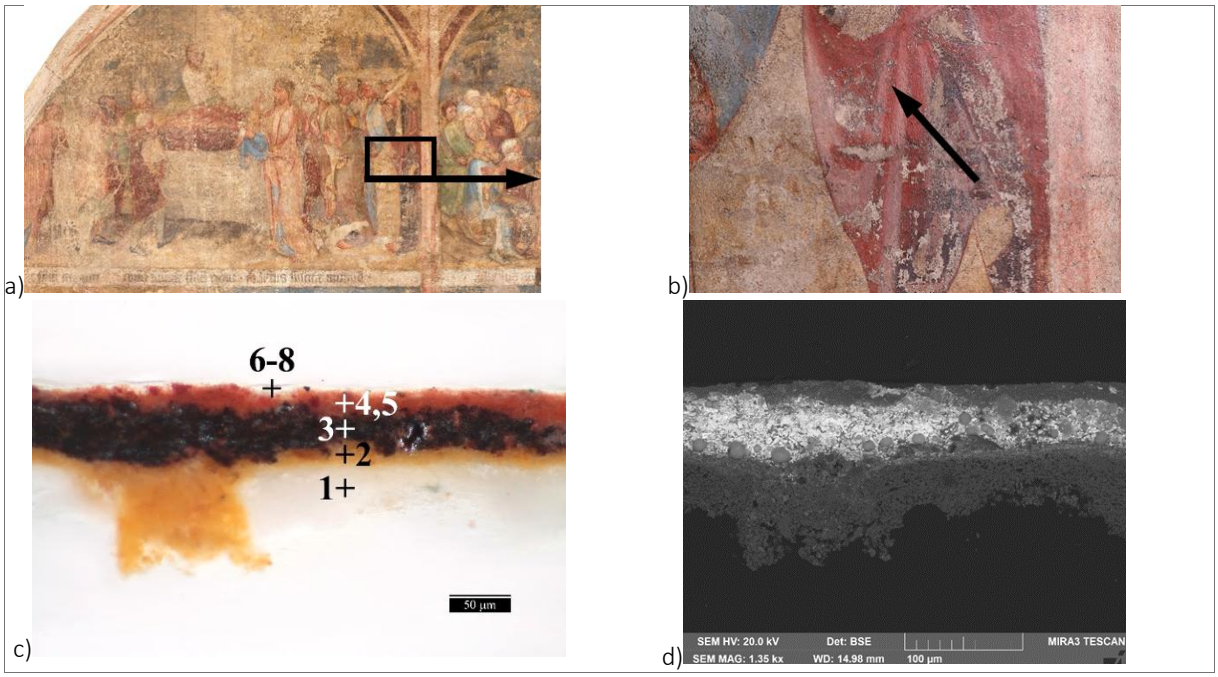


Figure 70a-d: Blackened painting of drapery with altered lead-based pigments beneath thick red overpainting, scene Jesus Feeds the Five Thousand and the Four Thousand, Bay 16(16+17): (a) sampling location, photogrammetry (©Jiří Vidman) with (b) detail image (©Jiří Vidman), c) cross-section OM–VIS and SEM – BSE ©Petra Lesniaková.

8.4 Problematic Phenomena and Associated Risk Factors

Particular attention was paid to potentially problematic or risk-related phenomena considered from aesthetic, conservation, and technological perspectives. In this respect, the investigation focused on contamination by soluble salts and degradation products, alterations of pigments and organic binders—including changes in their chemical composition and colour—as well as on the causes of veiling, surface gloss, and delamination. From the perspective of future conservation, the most serious risks are associated with the extensive alteration of lead-based pigments resulting in the formation of dark

plattnerite, the presence of multiple ageing synthetic polymer coatings (Table 9), and contamination by various soluble salts (Table 10).

The most significant and problematic alteration—both aesthetically and in terms of future conservation and presentation—is the extensive transformation of lead-based pigments into dark lead dioxide (PbO_2, plattnerite, Figure 70). This change can be expected wherever visual darkening of historic paint layers is suspected.

Organic surface coatings, often consisting of synthetic polymer fixatives, also pose a significant risk to the wall paintings. Their impact is evident in both the appearance and the physical condition of the paintings. These coatings frequently produce glossy, smooth surfaces and drips while progressive yellowing further reduces legibility and alters the original appearance. Owing to their presence, often considerable cumulative thickness, and potential material incompatibility with the historic painting structure, they may contribute to localised flaking of the paint layers or the plaster surface (Figure 71). On the surfaces of the micro-samples from Bays 1(1) and 10(10), µFTIR analysis identified coatings based on polyacrylates and poly(vinyl acetate). Furthermore, phthalates were identified by GC-MS in samples of blue-panted areas pointing to the presence of synthetic polymers.

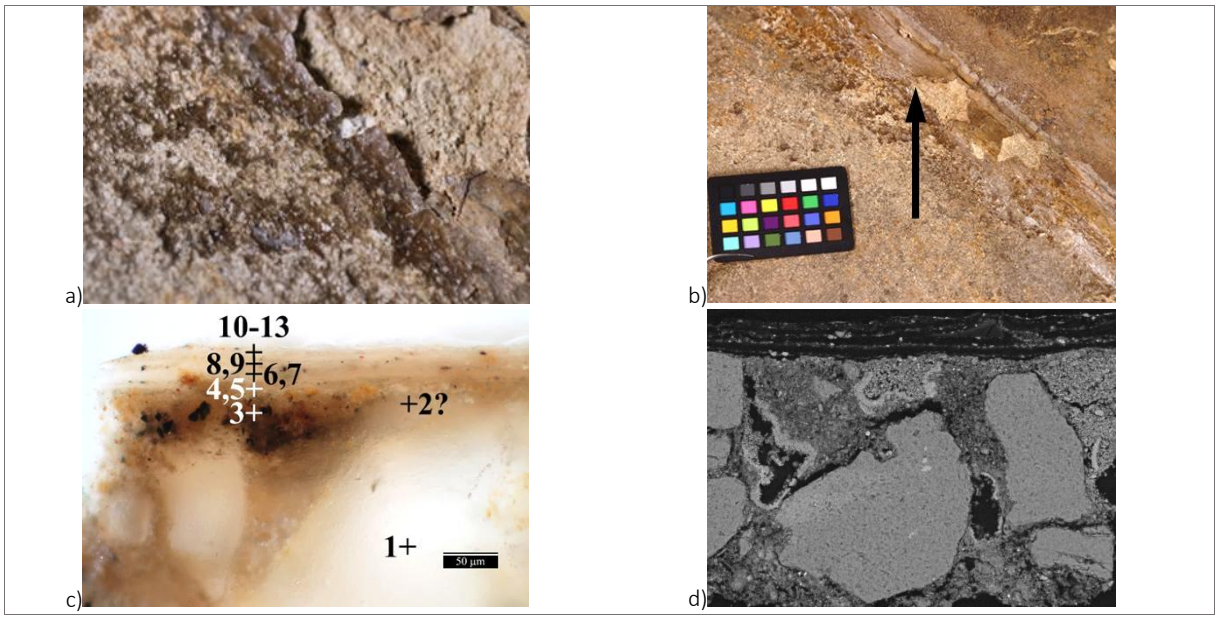


Figure 71: Stratigraphy of at least five organic coatings on the paint surface at the edge of Bay 10(10): (a, b) sampling location, detail, showing layer delamination and material loss (©Jan Vojtěchovský, Daniela Jakubů, Petra Lesniaková); (c) cross-section, OM–VIS layers 3–10 represent organic coatings, possibly retouching or deposit layers, with a total thickness of up to 40 µm; polyacrylates were identified on the sample surfaces by µFTIR; (d) cross-section, SEM–BSE. ©Petra Lesniaková.

The analysed fragments of intonaco, painting layers and surfaces of wall paintings show increased levels of calcium sulphate dihydrate ($CaSO_4 \cdot 2H_2O$, Figure 72) and chlorides. Due to sampling limitations, the presence of additional salts cannot be ruled out, as suggested by non-invasive analyses.

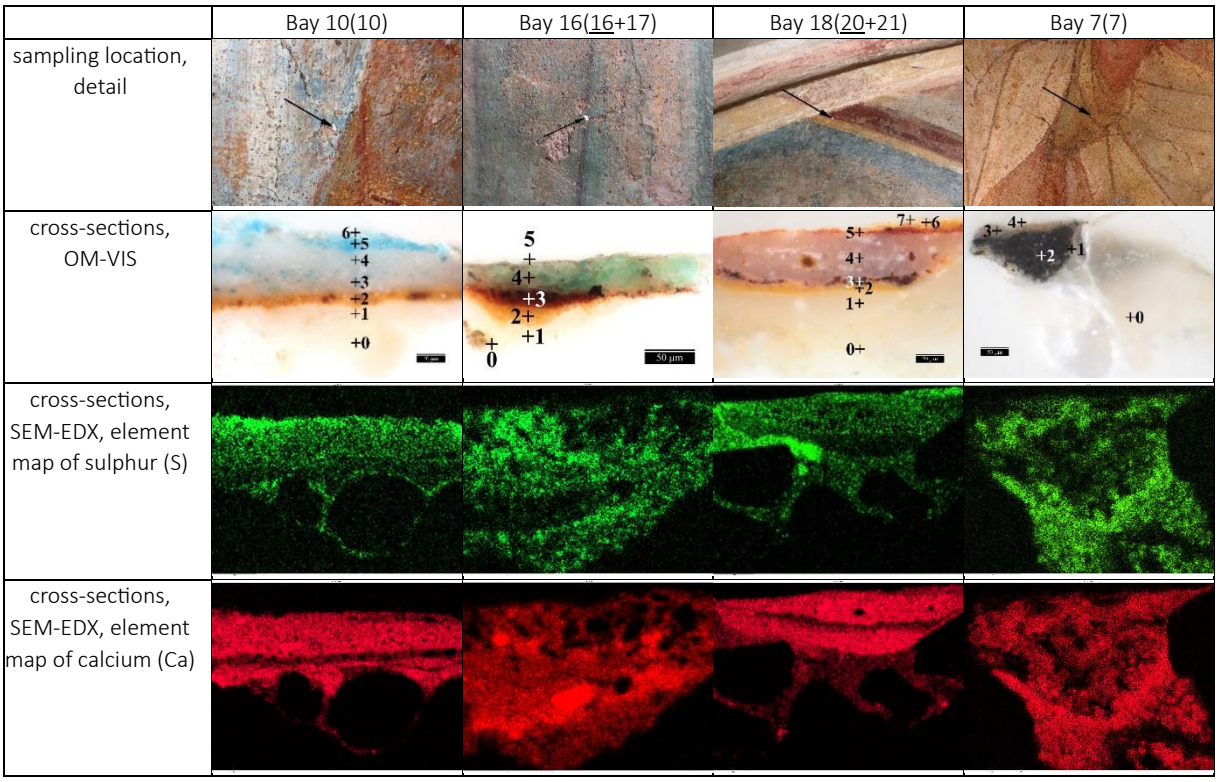


Figure 72: Localisation of calcium sulphate dihydrate in cross-sections, with corresponding microphotographs OM–VIS and elemental maps SEM–EDX of sulphur (S) and calcium (Ca) ©Lesniaková. Localisation of sampling areas ©Jan Vojtěchovský, Daniela Jakubů, Petra Lesniaková.

9 WP 8: Comprehensive Comparison and Evaluation of the Results of all Parts of the Survey and Recording

→ Corresponding chapter in the final report: Chapter 4 Towards a Conservation Plan: Recommendations and Implementation Framework

Work Package 8 brought together the results of all other work packages and formed the basis for the recommendations presented in *Chapter 4 Towards a Conservation Plan: Recommendations and Implementation Framework* of the main section of the final report and visualised in Figure 74.
The recommendations are intended as guidance rather than prescriptive requirements and may be implemented progressively according to available resources, feasibility, and management priorities. They are designed to support Emmaus Abbey, the responsible heritage authorities, and other stakeholders in planning and prioritising future conservation measures. They are intended to be realistic, adaptable, and compatible with the Abbey's continuing religious function, available resources, and the needs of its residents, staff, and visitors, recognising that the wall painting cycle forms part of a living heritage site. As an indicative structure, implementation may be organised in three phases. These phases are not strictly sequential but describe a general progression from organisational and preventive foundations towards testing, evaluation and possible wider implementation.
Regular and continuous exchange between the members of the project team was essential for bringing together the results from archival research, visual examination, imaging, material investigation, environmental assessment, risk assessment, and stakeholder discussions. The international colloquium held in mid-2025 represented an important milestone in concluding and discussing the project results with a broader professional audience. A particularly important step towards this synthesis was the fifth in-person project meeting, during which the findings from the individual work packages were jointly reviewed and used to develop the recommendations and implementation framework (Figure 73).

Figure 73: Impressions of in-person meeting in Cologne January 2026, DBU-funded project AZ 38228/01. Images © Daniela Jakubů, Kateřina Krhánková, Petra Lesniaková, Dennis Mitschke, Rebecca Tehrani.

The main outcome of WP 8 is the schematic framework shown below, which summarises the Levels of Action, the Phased Implementation Strategy, and the Indicative Conservation Scenarios.

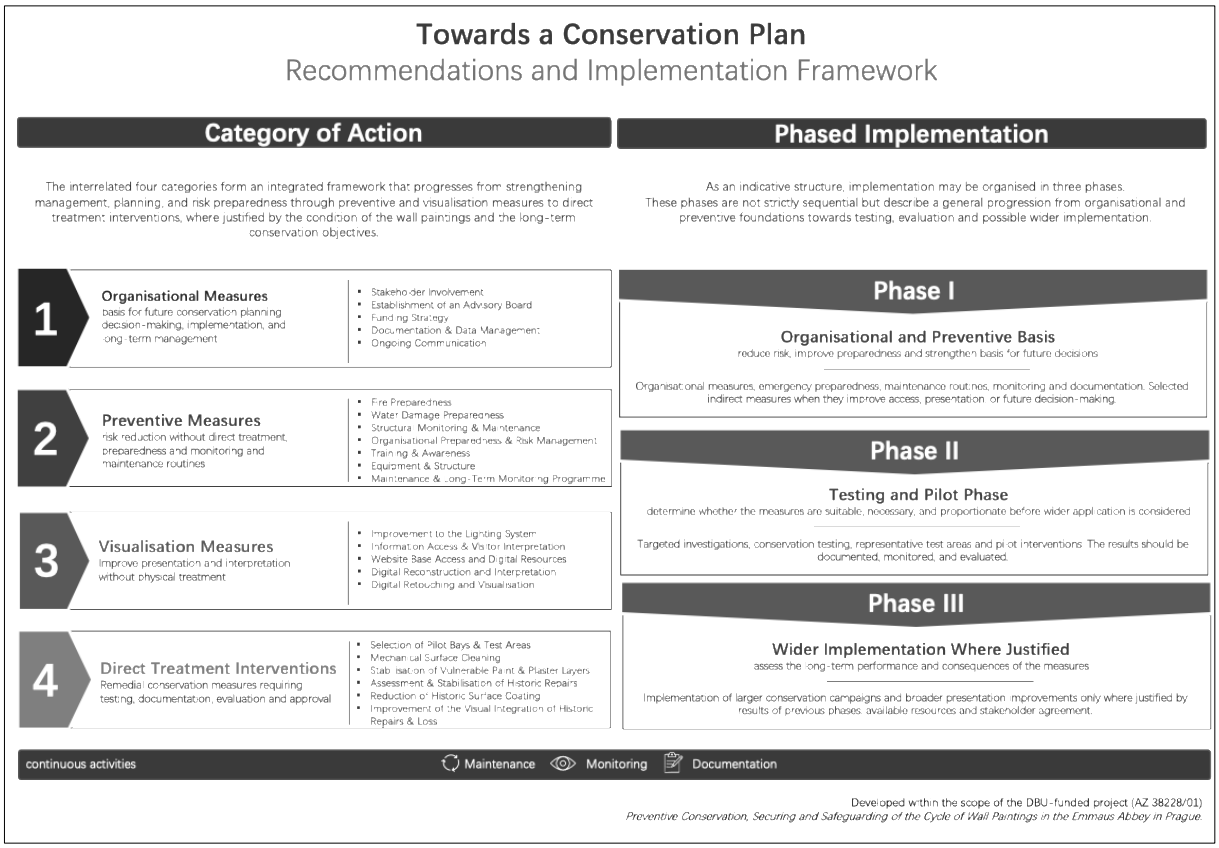


Figure 74: Visualisation of the Recommendations and Implementation Framework developed as a result of the DBU- funded project, AZ 38228/01. Synthesis and Illustration ©Rebecca Tehrani and Adrian Heritage.

10 WP 9: Preparation and Organisation of the International Colloquium

→ Corresponding chapters in the final report: Chapter 2.10 Preparation and Organisation of the International Colloquium (WP9), Chapter 3.8 Dissemination, Chapter 7 Public Relations

The *International Colloquium on Murals Preservation* was held at the Emmaus Abbey from 22 to 24 May 2025. The colloquium formed one of the central dissemination activities of the DBU-funded project and provided an opportunity to present, discuss, and reflect on the project results within an international professional context.

The event was conceived not only as a concluding presentation of the project's findings, but also as a platform for exchange between conservation professionals, researchers, heritage authorities, representatives of cultural institutions, students and representatives of Emmaus Abbey as the owner and host institution. It brought together 105 participants from 11 countries from different career stages and professional backgrounds.

The programme combined project presentations, expert talks, site-based exchange, moderated group discussions, and an optional excursion. It provided a format in which the project's methodological results could be discussed in relation to broader questions of preventive conservation, risk assessment, wall painting conservation, heritage management, presentation, and long-term decision-making.

The following overview documents the structure of the three-day programme and the main formats through which project results, expert perspectives, and stakeholder discussions were brought together.

10.1 Concept and Preparation

The colloquium was planned as an international professional event hosted at Emmaus Abbey, thereby allowing the project results to be presented directly within the architectural and functional context of the cloister and the wall painting cycle. This setting was essential for the aims of the event, as many of the issues addressed by the project, including environmental conditions, current use, accessibility, risk management, and future conservation planning and presentation, can only be fully understood in relation to the physical site and its ongoing use as a living heritage site.

The preparation of the colloquium included the development of the programme structure, the coordination of project and invited contributions, communication with participants, logistical organisation at Emmaus Abbey, and the integration of student involvement. Preparatory to the colloquium, a programme and a book of abstracts were finalised and circulated among the attendees. The abstracts are not reproduced here, as the contributions will be incorporated into the forthcoming project publication.

Registration and participant management were organised through the online platform eventim. Participation in the colloquium was free of charge, supporting broad professional access and student involvement. Registration was possible for the full three-day programme as well as for individual days.

The programme was designed to combine different forms of knowledge exchange. Formal presentations introduced the methods and results of the project and placed them in dialogue with external professional perspectives. Site-based exchange enabled participants to relate the findings to the specific context of the cloister. group discussions provided an interactive format for reflecting on future conservation, preventive measures, risk management, presentation, and stakeholder involvement. The optional excursion extended the comparative perspective to further examples of medieval wall painting in Prague.

Students from the University of Pardubice contributed to the preparation and on-site organisation of the event. Their involvement supported the practical implementation of the International Colloquium

and formed part of the project's wider objective to involve emerging conservation professionals in interdisciplinary heritage research.

10.2 Programme Overview: Day 1

10.2.1 Welcome and Introduction to the Project

The first day introduced the aims, structure, and context of the DBU-funded project. Following the welcome of the participants by Brother Dominik from Emmaus Abbey, the project was introduced by Mrs Fuhrmann. The opening session situated the colloquium within the cooperation between the project partners, Emmaus Abbey, the DBU as the funding party and the three research institutions.

The talks addressed the significance of the Emmaus Cycle as a unique medieval wall painting ensemble within the cloister of Emmaus Abbey. They also outlined the specific challenges of the site, where the preservation of an important medieval wall painting cycle has to be considered in relation to the architectural setting, its conservation history, present-day monastical use, access, and long-term heritage management

10.2.2 Presentation of the Emmaus Cycle and Project Results

The first day continued with presentations on the Emmaus Cycle and the main results of the project. Basic information on the history, iconography, the painting technique, conservation history, and present condition and environmental context of the wall paintings was presented in order to provide a common basis for the following discussions.

The project results were introduced through the main methodological strands: archival research, visual examination and mapping, photographic and photogrammetric documentation, imaging methods, material analysis, environmental assessment, monitoring, and risk assessment. Particular emphasis was placed on the largely non-invasive character of the investigative approach: Optical investigation, imaging methods, non-invasive analysis, environmental surveys, monitoring, and risk assessment were applied to establish a broad understanding of the wall paintings, thereby reducing the number of microsamples.

The presentations showed how these methods complemented one another and contributed to a differentiated understanding of the wall painting cycle, its condition, earlier interventions, and the factors affecting its future preservation. Archival research supported the interpretation of earlier interventions; visual examination and mapping established a systematic overview of technique and condition; imaging methods helped to identify material differences and their distribution; analytical investigations provided information on pigments, binders, alteration products, restoration materials, and stratigraphy; and the ABC Method risk assessment reflected on current and potential risks.

10.2.3 Site-Based Exchange

As the colloquium took place at Emmaus Abbey, the first day also allowed participants to relate the presented findings directly to the cloister and its current use. This site-based exchange supported discussion of the relationship between the wall paintings, the building envelope, visitor use, heating and ventilation routines, light exposure, moisture-related phenomena, and maintenance practices.

The direct experience of the site also helped to contextualise the project's risk-based approach, particularly with regard to the main risks identified in the ABC assessment: fire, water, structural damage, and risks associated with use.

10.3 Programme Overview: Day 2

10.3.1 Expert Talks

The second day broadened the perspective beyond the Emmaus project. Invited international speakers presented research and conservation approaches from different European contexts, including examples from Germany, Italy, and the Czech Republic. The expert talks placed the Emmaus Cycle within a wider field of medieval wall painting conservation and heritage management. They were particularly relevant because they presented different decisions on conservation and presentation of complex medieval wall painting ensembles. The contributions addressed medieval wall painting techniques, the relationship between investigation and intervention, the relevance of conservation history for future decision-making, the visual and ethical implications of presentation choices, and the balance between conservation, accessibility, and interpretation. In this way, the second day opened a comparative perspective shaped by different professional and institutional traditions in Europe.

10.3.2 Structured Group Discussions

In the afternoon of the second day, moderated group discussions were held on future strategies for the preservation and presentation of the Emmaus Cycle. All participants were invited to take part. The discussions were moderated and recorded by members of the project team and organised in four groups, allowing participants from different professional backgrounds to contribute their perspectives in a smaller discussion setting.

After a brief introduction round, the groups discussed the following questions:

- What is your main takeaway from the DBU project and the presentations? What did you find particularly important or interesting?
- What should the next conservation treatment on the Emmaus Cycle include? Is it necessary to change the concept from the 1960s, and if so, how?
- What relevant aspects, if any, are missing or need more attention?

The results of the group discussions were subsequently presented in the plenary session. Feedback on the project, the programme and structure of the Colloquium was positive. Participants appreciated the opportunity to contribute to the discussion. The recorded outcomes informed the development of the recommendations and the phased framework.

10.4 Programme Overview: Day 3

On the third day, 60 participants took part in the optional excursion to the Church of St Apollinaire in New Town, wall paintings in the Old Town Hall and in the Stone Bell House in Prague. A detailed explanation of the iconography of the paintings was given by Jan Dienstbier. The excursion complemented the formal presentations and group discussions by allowing selected questions of wall painting conservation, iconography, architectural context, presentation, and heritage management to be discussed in situ.

10.5 Reflection

The colloquium communicated the project results to an international professional audience and provided a structured forum for professional exchange. By combining project presentations, invited expert contributions, site-based exchange, moderated group discussions, and an optional excursion, the programme allowed the findings from the Emmaus project to be discussed alongside examples from other European sites and in relation to different conservation traditions and professional practices. The group discussions added a participatory dimension by collecting feedback on future strategies for conserving and presenting the Emmaus Cycle. All contributions presented at the colloquium as well as a reflection on the structured group discussions will be disseminated through the forthcoming English-

language book publication entitled *The Emmaus Cycle: Wall Painting in Context and Close Up. Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague.* In this way, the colloquium formed an important link between the dissemination of the project results, their critical discussion within the professional community, and their further development in published form. The colloquium therefore functioned not only as a dissemination activity, but also as part of the project's reflective and participatory process. It strengthened professional exchange and supported conservation education. It provided a forum for discussing the project's risk-based, and largely non-invasive approach through the concrete example of the Emmaus Cycle in a historic building that remains in active use.

10.6 Registrations

A total of 105 individuals registered for the colloquium. Since registration was possible for individual programme days, the day-specific numbers do not add up to the total number of registered attendees (Table 7). The optional excursion on the third day required prior registration.

Table 7: Number of registrations for the International Colloquium on Murals Preservation held at the Emmaus Abbey in Prague (22-24 May 2025), DBU-funded project AZ 38228/01

Programme	Date	Registrations
Day 1 Colloquium	22 May 2025	99
Day 2 Colloquium and Group Discussions	23 May 2025	93
Excursion	24 May 2025	60
Total registrations		105

Participants came from 11 countries, with the largest groups registered from the Czech Republic, Germany, and Austria (Table 8). The professional backgrounds of the attendees reflected the interdisciplinary character of the colloquium. The largest groups were university or academic staff and researchers, freelance conservators, students, and representatives of cultural heritage institutions (Table 9).

Table 8: Countries represented among registered attendees at the International Colloquium on Murals Preservation held at the Emmaus Abbey in Prague (22-24 May 2025), DBU-funded project AZ 38228/01

Country	Number of registrations
Algeria	1
Armenia	2
Austria	13
Czech Republic	61
Estonia	1
France	2
Germany	18
Italy	2
Hungary	3
Norway	1
United Kingdom	1

Table 9: Professional backgrounds represented among registered attendees at the International Colloquium on Murals Preservation held at the Emmaus Abbey in Prague (22-24 May 2025), DBU-funded project AZ 38228/01DBU-funded

Position / professional background	Number of registrations
University / academic staff / researchers	36
Freelance conservators	24
Students	18
Cultural heritage institution	16
Museum / gallery	5
Own company	4
Emmaus Abbey	2

10.7 Affiliation of Attendees

The following list provides an overview of the institutional and professional affiliations represented among the attendees of the colloquium. It is based on the information provided during registration and does not constitute a list of participating institutions or project partners

- Armenian Scientific Research Center of Mural Restoration
- Academy of Fine Arts Vienna, Institute for Conservation-Restoration
- artIMAGING
- Birkbeck, University of London
- Brandenburgisches Landesamt für Denkmalpflege und Archäologisches Landesmuseum
- Český směr
- Czech Academy of Sciences, Institute of Art History
- Dennis Mitschke – Restaurierungen
- Deutsche Bundesstiftung Umwelt
- EGTPH RASOUL
- Emmaus Abbey
- Escola Superior de Música de Catalunya
- Estonian Academy of Arts
- Galerie hlavního města Prahy
- Hochschule für Bildende Künste Dresden
- Hungarian Academy of Fine Arts, Conservation-Restoration Department
- Institute of Theoretical and Applied Mechanics of the Czech Academy of Sciences
- Kunsthistorisches Museum Wien
- Landesamt für Denkmalpflege Baden-Württemberg
- Masaryk University, Faculty of Science, Department of Chemistry
- Museum of Archaeology, University of Stavanger
- National Heritage Institute
- National Technical Museum, Prague
- Nature Conservation Agency of the Czech Republic
- Palacký University Olomouc
- Sapienza and Università degli Studi di Palermo
- Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Firenze e le province di Pistoia e Prato
- Staatliche Akademie der Bildenden Künste Stuttgart
- Stiftung Preußische Schlösser und Gärten Berlin-Brandenburg
- Technische Hochschule Köln, Cologne Institute of Conservation Sciences
- Technische Universität Dresden
- The Academy of Fine Arts Prague
- University of Innsbruck
- University of Pardubice, Faculty of Restoration, Litomyšl

10.8 Colloquium Programme

11 Public Relations

→ Corresponding chapters in the final report: Chapter 3.8 Dissemination, Chapter 7 Public Relations

Public relations and dissemination were integral parts of the project throughout its duration. Activities included media coverage, institutional websites and social media communication, the development of a dedicated project website, and scholarly publications. The material presented in this chapter documents the principal means through which the project's objectives, progress, and outcomes were communicated to both professional and public audiences.

11.1 Media Coverage

In 2023, the project was introduced to the public through the partners' websites. This was followed by considerable media interest. A short article appeared in the regional newspaper *Chrudimský deník* on 10 February 2023, after which the project received coverage in national media. On 8 February 2023, a short interview was broadcast on Czech Radio Plus, and on 15 March 2023 the project was featured by Czech Television in the programme *Události v kultuře* (Figure 56). A further interview was recorded for Czech Radio and broadcast as part of its news coverage on 17 March 2023, after which it was also published on the Czech Radio website.

Media interest continued throughout 2024. In particular, the multispectral imaging campaign undertaken using the *Phase One* Rainbow Multispectral Imaging Solution between 22 January and 5 February 2024 attracted considerable attention from the Czech media. The survey work carried out in the cloister of the Emmaus Abbey was subsequently featured by a number of national media outlets.

Figure 75: The media showed their interest on the survey in the cloister of the Emmaus Abbey. Photo shows Jan Vojtěchovský. Události v kultuře (Events in culture) on ČT Art (Czech Television) on Wednesday 15 March 2023 (start time of the programme - 6:01).

The survey was featured in the programme *Věda 24* ('Science 24') on ČT 24 on 4 February 2024 (Figure 57). It received further coverage on ČT 24 on 5 February 2024 in the programme *Zprávy v 16* ('News at 16') and, in greater detail, on 6 February 2024 in the programme *Studio 6*. Czech Radio likewise

produced a report on the multispectral imaging campaign with the *Phase One* Rainbow System (Figure 58).

Media interest continued into 2025. In connection with the colloquium *Preventive Conservation, Securing and Preservation of the Cycle of Murals in the Emmaus Monastery in Prague*, held from 22 to 24 May 2025, the project team prepared a press release for the Czech News Agency.

Figure 76: The media reported on the ongoing survey work in the cloister of the Emmaus Abbey. Photo shows Roland Lenz. Věda 24 (Science 24) on ČT 24 (Czech Television) on Sunday 4 February 2024 (start time of the programme - 7:57).

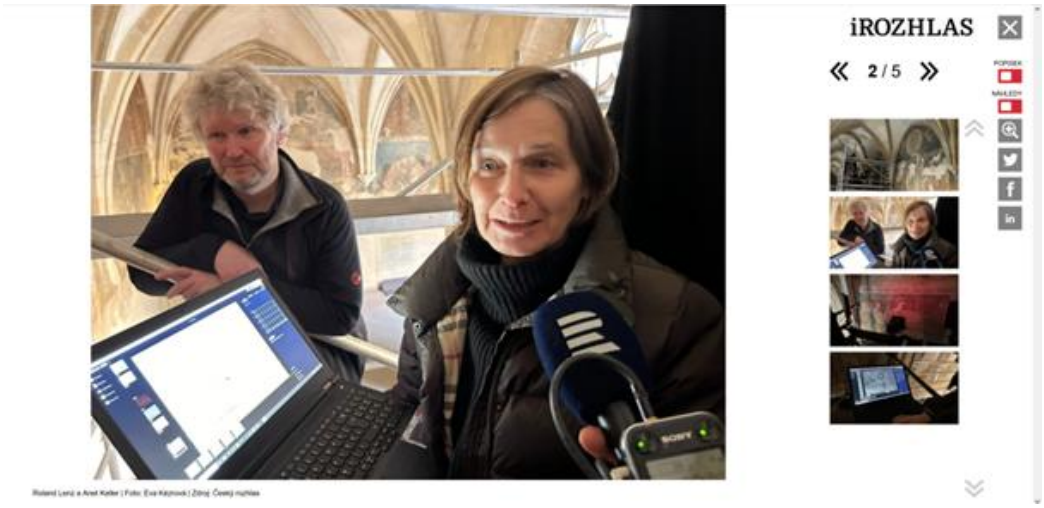


Figure 77: Czech Radio reported on the ongoing survey work in the cloister of the Emmaus Abbey. The photo shows Roland Lenz (left) and Annette T. Keller (right). News of the project appeared twice in the same place as part of the regular news coverage.

The publication of the project's results also attracted considerable media attention. Initial coverage appeared in the regional media, with reports published by *Náš Region* on 23 May 2025 and *Pražský Patriot* on 25 May 2025. This was followed by coverage in the national media. On 29 May 2025, Czech Radio broadcast several reports across its Radiožurnál, Plus, and Region channels. In addition to these broadcasts, a report on the colloquium was published on the Czech Radio news website *iROZHLAS.cz* on the same day. Table 10provides an overview of the media coverage generated during the project:

Table 10: List of Media Coverage during the Project period 01/2023-06/2026, DBU-funded project AZ 38228/01.

Date	Medium/ Programme	Format	Link / Reference
8 February 2023	Czech Radio Plus	Radio interview	No public link
10 February 2023	*Chrudimský deník*	Regional newspaper report	No public link
15 March 2023	Czech Television, *Události v kultuře,* reporting time 6:01-8:35	Television report	https://www.ceskatelevize.cz/porady/1097206490-udalosti-v-kulture/223411000120315/
17 March 2023	Czech Radio	Radio report / online article	https://cesky.radio.cz/fresky-v-emauzech-zkoumaji-odbornici-urci-postup-restaurovani-vzacnych-maleb-z-8778173
4 February 2024	Czech Television, *Věda 24,* start time of the programme - 7:57	Television report	https://www.ceskatelevize.cz/porady/11633975240-veda-24/224411058340005/
5 February 2024	Czech Television, *Zprávy v 16,* start time of the report in the programme: 18:40	Television report	https://www.ceskatelevize.cz/porady/10253214196-zpravy-v-16/224411016000205/
6 February 2024	Czech Television, *Studio 6*	Television report	https://www.ceskatelevize.cz/porady/1096902795-studio-6/224411010100206/
February 2024	Czech Radio / IRozhlas.cz	Radio report / online article	https://www.irozhlas.cz/kultura/vytvarne-umeni/restaurovani-kamera-malby-emauzsky-klaster_2402042019_jud
23 May 2025	*Náš Region*	Regional media report	https://nasregion.cz/unikatni-stredoveke-malby-v-emauzich-odhaluji-sva-tajemstvi-406587/
25 May 2025	*Pražský Patriot*	Regional media report	https://www.prazskypatriot.cz/odbornici-prozkoumali-stav-nastennych-maleb-ze-14-stoleti-v-emauzich/
29 May 2025	Czech Radio Radiožurnál, *Hlavní zprávy*, time 7:02:54	Radio broadcast, Main News	https://program.rozhlas.cz/zaznamy#/radiozurnal/2025-05-29
29 May 2025	Czech Radio Radiožurnál, *Ranní interview*, time 7:50:52	Radio broadcast, Morning Interview	https://program.rozhlas.cz/zaznamy#/radiozurnal/2025-05-29
29 May 2025	Czech Radio Plus, *Ranní Plus*, time 7:26:10	Radio broadcast, Morning Plus	https://program.rozhlas.cz/zaznamy/plus#/plus/2025-05-29
29 May 2025	Czech Radio Region, *Zprávy*, time 8:07	Radio broadcast, News	https://program.rozhlas.cz/zaznamy#/pardubice/2025-05-29
29 May 2025	Czech Radio Radiožurnál, *Hlavní zprávy*, time 14:03:12	Radio broadcast, Main News	https://program.rozhlas.cz/zaznamy#/radiozurnal/2025-05-29
29 May 2025	IRozhlas.cz	Online article	https://www.irozhlas.cz/veda-technologie/veda/stredoveke-malby-v-emauzskem-klastere-neposkodila-nejvic-valka-velkym-problemem_2505292330_jkd

11.2 Institutional Web and Social Media Communication

For the presentation of the project, a page on all three universities was set up:

- University of Pardubice: https://fr.upce.cz/fr/mezinarodni-projekt-pro-detailni-pruzkum-nastennych-maleb-tzv-emauzskeho-cyklu-praze
- Staatliche Akademie der Bildenden Künste Stuttgart: https://www.abk-stuttgart.de/forschung/konservierung-und-restaurierung-von-kulturgut/konzeptentwicklung-zur-bewahrung-des-wandmalereizyklus-im-kreuzgang-des-emmausklosters-in-prag/
- Technische Hochschule Köln: https://www.th-koeln.de/kulturwissenschaften/konzept-zur-praeventiven-konservierung-sicherung-und-bewahrung-fuer-den-wandmalerei-zyklus-im-kreuzgang-des-emmausklosters-in-prag_105561.php

During the course of the project further information was published through the universities web sites, to report on imaging campaigns (Figure 78), on-site surveys, Project meetings and to announce the International Colloquium:

- Staatliche Akademie der Bildenden Künste Stuttgart: https://www.abk-stuttgart.de/wp-content/uploads/2025/04/VA_22052025_DBU_Colloquium_Flyer.pdf
- Technische Hochschule Köln: https://www.th-koeln.de/hochschule/emmauskloster-in-prag-wandmalereien-in-not_105772.php
- University of Pardubice : https://fr.upce.cz/en/academic-staff-of-the-faculty-of-restoration-at-project-meeting-in-cologne

Figure 78: Information about the surveys was also published on the website of the Faculty of Restoration at the University of Pardubice.

Furthermore, an article about the ongoing survey was published in the University of Pardubice journal *My UPCE* (pp. 34–35) (Figure 79).

Figure 79: An article about the ongoing survey was published in the University of Pardubice journal My UPCE (pp. 34-35). https://www.upce.cz/sites/default/files/public-files/myupce/111/111.html

Additionally posts on social media reported about the project activities such as in-person project meetings, imaging campaigns, student involvement during the campaign in November 2024 and the International Colloquium. The posts were published on the social networks of FR UPCE and Emmaus Abbey. Some examples are listed in the table below (Table 11).

Table 11: Institutional web and social media references, DBU-funded project AZ 38228/01.

Date /Period	Institution/ Platform	Format	Link / *R*eference
2023	University of Pardubice, Faculty of Restoration	Project information webpage	https://fr.upce.cz/fr/mezinarodni-projekt-pro-detailni-pruzkum-nastennych-maleb-tzv-emauzskeho-cyklu-praze
2023	ABK Stuttgart	Project information webpage	https://www.abk-stuttgart.de/forschung/konservierung-und-restaurierung-von-kulturgut/konzeptentwicklung-zur-bewahrung-des-wandmalereizyklus-im-kreuzgang-des-emmausklosters-in-prag/#0_h3_das-projekt
2023	TH Köln	Project information webpage	https://www.th-koeln.de/kulturwissenschaften/konzept-zur-praeventiven-konservierung-sicherung-und-bewahrung-fuer-den-wandmalerei-zyklus-im-kreuzgang-des-emmausklosters-in-prag_105561.php
25 February 2023	Emmaus Abbey / Facebook	Social media post	https://www.facebook.com/story.php?story_fbid=237484135300687&id=100071173073633&rdid=Gwu02RQhs131JHdR
July 2023	TH Köln	Online post	https://www.th-koeln.de/hochschule/emmauskloster-in-prag-wandmalereien-in-not_105772.php
7 February 2024	Faculty of Restoration, University of Pardubice / Facebook	Social media post	https://www.facebook.com/story.php?story_fbid=880550330746274&id=100063739442187&rdid=XN4YreqB0riJwcd7
2024	University of Pardubice, *My UPCE*	University of Pardubice, *My UPCE*	https://www.upce.cz/sites/default/files/public-files/myupce/111/111.html
2 December 2024	Faculty of Restoration, University of Pardubice / Facebook	Social media post on student campaign	https://www.facebook.com/share/p/15dfMdiC6g/
22 May 2025	University of Pardubice / Facebook	Social media post on colloquium	https://www.facebook.com/univerzita.pardubice/posts/1132780975553372
4 June 2025	Faculty of Restoration, University of Pardubice / Facebook	Social media post on colloquium	https://www.facebook.com/share/p/16QWJKm6pg/

Date /Period	Institution/ Platform	Format	Link / Reference

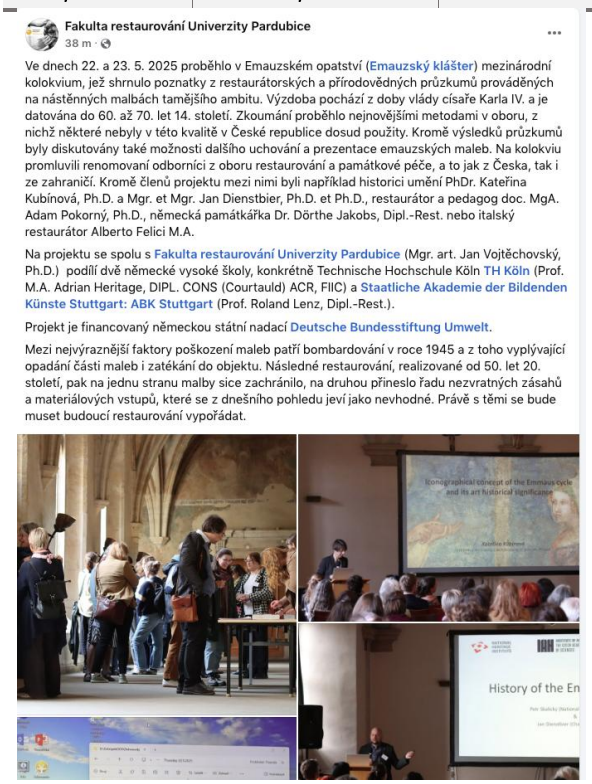


Figure 80: DBU colloquium was reported on Facebook Website - Faculty of Restoration, University of Pardubice https://www.facebook.com/share/p/16QWJKm6pg/

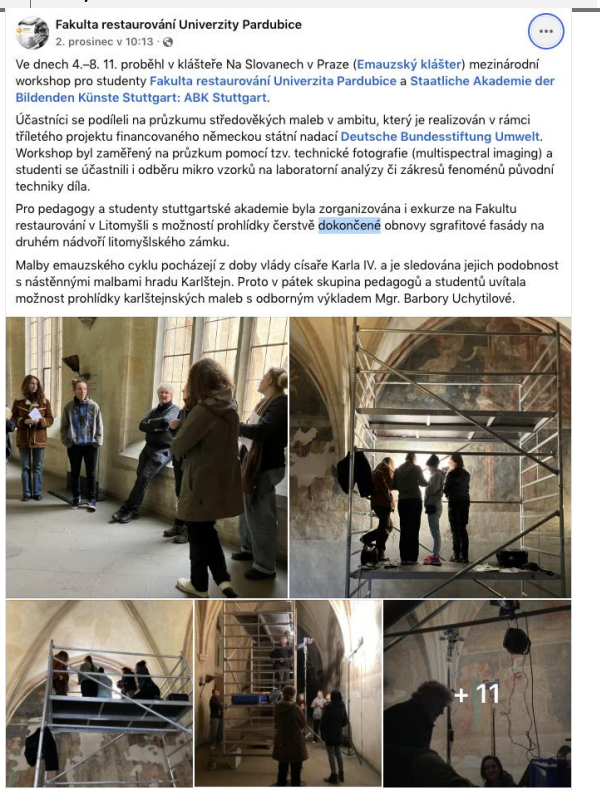


Figure 81: University of Pardubice Facebook page is bringing an information about the student's campaign in November 2024, with the presence of ABK Stuttgart and University of Pardubice students. https://www.facebook.com/share/p/15dfMdiC6g/

11.3 Project Web Site

During the fourth reporting period, the project team initiated the development of a website to present the project's results to both specialist and public audiences. Following agreement on the overall concept, web designer Jan Sládek, who had previously developed a website for another research project on medieval wall paintings, was commissioned to prepare the site. Jiří Vidman, who carried out the project's photogrammetric survey of the Emmaus Cycle, was commissioned to calibrate selected historical photographs for integration into the website. The associated costs were agreed by the representatives of Emmaus Abbey, who are funding the website.

The website is centred on a virtual 3D tour of the cloister created using Matterport technology, enabling visitors to explore 28 viewing stations and navigate through the cloister, the Imperial Chapel, and the adjoining part of the church from different perspectives (Figure 63). From the virtual tour, users can access individual bays and selected details of the wall paintings, presented in high-resolution 2D views (Figure 64).

The website is divided into two sections. The public section provides an introduction to the project, the virtual tour, detailed views of the wall paintings, and iconographic descriptions. A specialist section, currently under development, will present the principal scientific and conservation results of the project. In addition, the website will integrate historical photographs of the cloister from the late nineteenth century onwards as georeferenced layers within the photogrammetric survey, enabling users to compare the paintings over time.

Tourist part: https://logiq.cz/client/emauzy/cz/homepage
Example of the expert part on Bay 5(5): https://logiq.cz/client/emauzy/cz/cyklus-maleb/pro-5

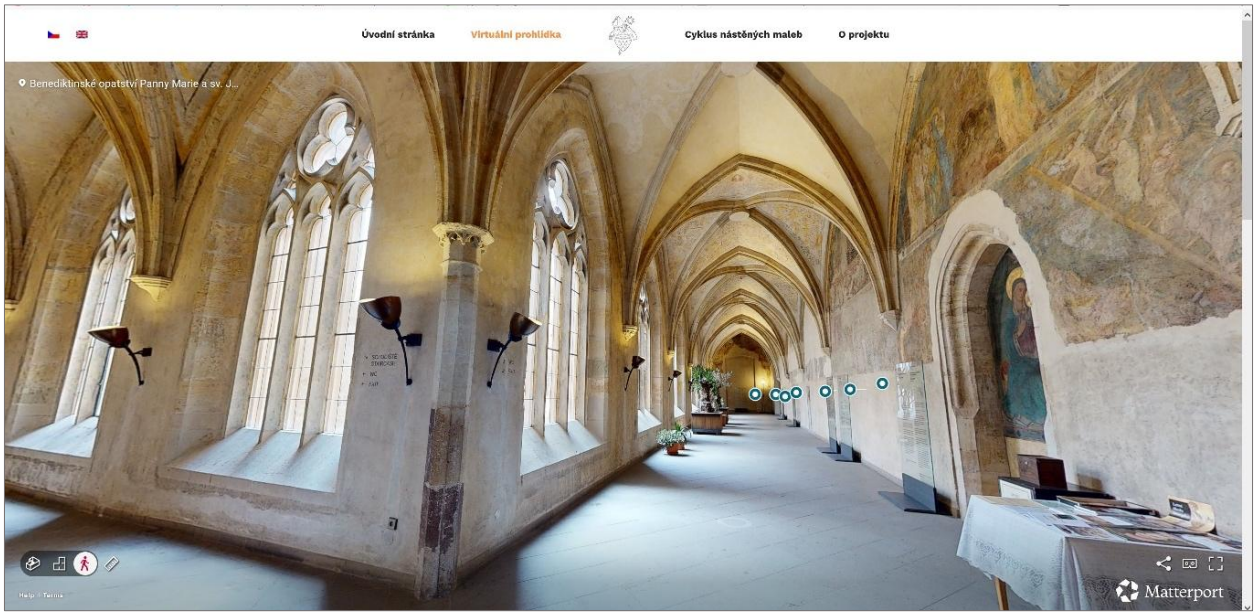


Figure 82: Example of a virtual 3D tour of the cloister prepared by Matterport technology.

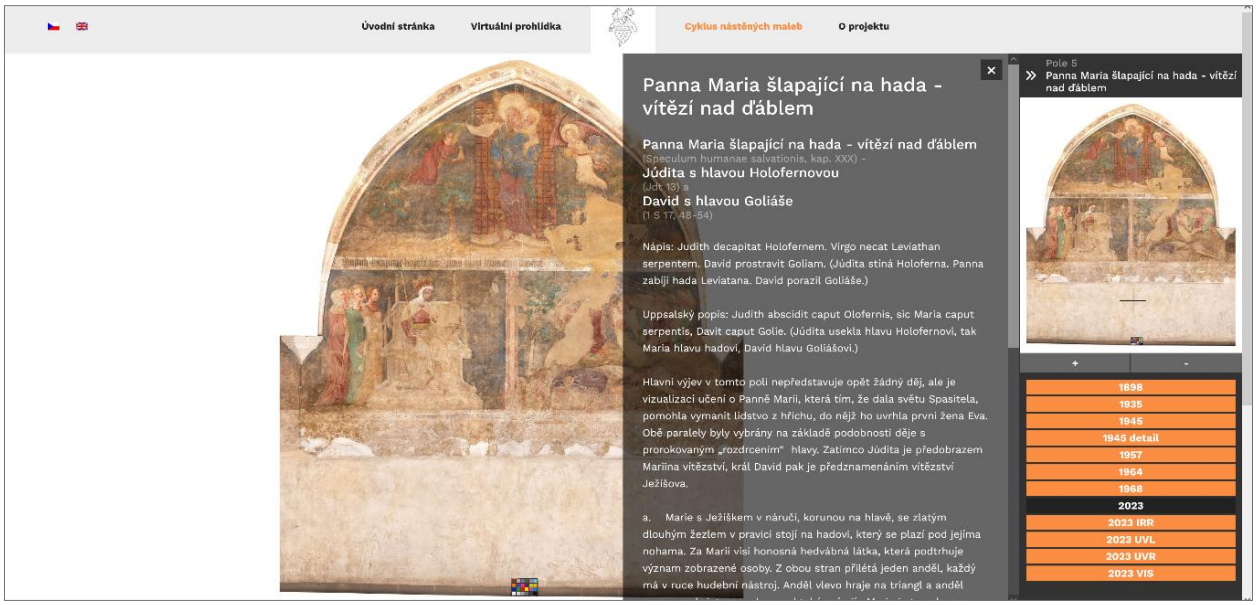


Figure 83: Example of view of bay 5(5) with the iconographic description a possibility to switch in between different historical photos and spectral imaging layers.

11.4 Publications

The main outcome from the project is a forthcoming richly illustrated English-language book publication titled *The Emmaus Cycle: Wall Painting in Context and Close Up. Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague.* The volume will document both the colloquium and the principal outcomes of the project and is currently planned for publication in 2027 by the University of Pardubice. It summarises the results of the project together with perspectives of external experts linked to the topic of preventive conservation, securing and preservation of the Emmaus Cycle, presented at the International Project Colloquium in May 2025.

Besides, also the final evaluation in the definition of the concept is being prepared. Likewise, an article for a peer-reviewed Czech journal from the monument heritage field is being prepared. The article focuses on a comparison of already published and newly gained information about the technique of the original fourteenth-century paintings of the Emmaus Cycle. The article addresses the Czech professional community and presents the results of the survey as well as up-to-date, mostly non-destructive survey techniques. The article is being prepared for the review process by the end of 2026.
The project was also presented to the professional community through conference and lecture contributions, including a presentation at the Czech Academy of Sciences and a poster presented at the TECHNART 2025, 6-9 May 2025, Perugia (Italy): Zöldföldi, J.; Angelin, E. M.; Sessa, C.; Mindermann, S.; Keller, A. T.; Schellbach, K.; Lenz, R. 2025. *From Spot to Imagery: Non-Invasive Investigation of Wall Paintings Using a Multi-Method Approach*. Poster presented at TECHNART 2025, 6–9 May 2025, Perugia, Italy.

11.4.1 Provisional Table of Content of the Forthcoming Book Publication

TITLE

The Emmaus Cycle: Wall Painting in Context and Close Up. Preventive Conservation, Securing and Safeguarding of the Cycle of Wall Paintings in the Emmaus Abbey in Prague.

FRONT MATTER

Editor's Introduction
Foreword 1 – The DBU Project
Constanze Fuhrmann
Foreword 2 – Significance of the Emmaus Painting Cycle
Representative of the Benedictine Abbey of Our Lady and St. Jerome in Emmaus, Karel Švejda
Acknowledgements
List of Contributors

PART I

Iconographical Concept of the Emmaus Painting Cycle and its Art Historical Meaning in Central Europe
Kateřina Kubínová
The History of the Emmaus Painting Cycle until 1945
Jan Dienstbier, Petr Skalický

PART II

Techniques and Materials of the Emmaus Painting Cycle Based on Visual Survey
Daniela Jakubů, Jan Vojtěchovský, Petra Lesniaková
Conservation of the Emmaus Painting Cycle in the 20th Century
Kateřina Krhánková, Jan Vojtěchovský
State of Preservation of the Emmaus Painting Cycle
Jan Vojtěchovský, Daniela Jakubů, Petra Lesniaková, Kateřina Krhánková
Multispectral Imaging Survey with the Rainbow System in Multiband and Narrowband
Katharina Schellbach, Roland Lenz
Decoding Wall Paintings: Material Investigation Using In Situ Multimodal Spectroscopy
Judit Zöldföldi, Petra Lesniaková, Katharina Schellbach, Clarimma Sessa, Eva Marisole Angelin, Simon Mindermann, Roland Lenz
Results of Laboratory Analysis of Physical Samples
Petra *Lesniaková, Judit Zöldföldi*

12 Lists

12.1 List of Figures

12.2 List of Tables

12.3 List of Charts

12.4 List of Abbreviations

ABK Stuttgart	Staatliche Akademie der Bildenden Künste Stuttgart
AT	Ambient temperature
AVU	Academy of Fine Arts in Prague
AZ	Aktenzeichen
BW	Black and White
CAS	Czech Academy of Sciences
CICS	Cologne Institute of Conservation Sciences
ČTK	Czech Press Office
DBU	Deutsche Bundesstiftung Umwelt
DP	Dew point
EDX	Energy-Dispersive X-Ray
e.g.	For example
ER-FTIR	External-Reflectance Fourier-Transform infrared spectroscopy
HSI	Hyperspectral imaging
i.e.	For instance
GC-MS	gas chromatography with mass spectroscopy

ICA	Independent component analysis
IR	Infrared
IRR	Infrared reflectance
IRRFC	Infrared reflectance false colour
MA-XRF	Macro-X-Ray Fluorescence
MB	Multiband
MPA	Materials Testing Institute (at the University of Stuttgart)
NB	Narrowband
MSI	Multispectral imaging
No.	Number
NPÚ	National Heritage Institute, Czech Republic
PCA	Principal component analysis
pFTIR	portable Fourier-transform infrared (spectroscopy)
pFTNIR	portable Fourier-transform near infrared (spectroscopy)
pRaman	portable Raman (spectroscopy)
pXRF	portable X-Ray Fluorescence
RGB	Red-Green-Blue
RH	Relative Humidity
SEM	Scanning Electron Microscopy
St	Saint
TH Köln	Technische Hochschule Köln
ÚDU AV ČR	Institute of Art History, Czech Academy of Sciences
UPCE FR	University of Pardubice, Faculty of Restoration
UV	Ultraviolet
UVIL	Infrared luminescence induced with ultraviolet light
UVL	Visible luminescence induced with ultraviolet light (ultraviolet luminescence)
UVR	Ultraviolet reflectance
UVRFC	Ultraviolet reflectance false colour
VIL	Infrared luminescence induced with visible light
VIS	Visible reflectance
WP	work package
µRS	micro Raman Spectroscopy
µFTIR	micro Fourier Transform Infrared Spectroscopy
µXRD	micro-X-Ray Diffraction