



Research and Educational Programme

INTERNATIONAL WORKSHOP IN CULTURAL HERITAGE CONSERVATION

„ Multispectral Imaging and 3D
Photogrammetric monitoring in Wall
Painting Conservation“

Gelati Monastery Complex

**July – November
2024**



გელათის რეაბილიტაციის კომიტეტი
GELATI REHABILITATION COMMITTEE

LEPL INTERNATIONAL EDUCATION
CENTER OF GEORGIA

EKA Eesti
Kunstiakadeemia

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Gelati wall painting conservation programme

The Gelati Monastery Complex, a UNESCO World Heritage site, is managed by the Patriarchate of Georgia through the Gelati Rehabilitation Committee. The committee's mission encompasses overseeing the site's rehabilitation, including projects such as the Gelati Wall Painting Conservation Programme.

The Gelati Wall Painting Conservation Programme focuses on preserving the historic paintings of the Gelati Monastery Complex through preventive and passive measures as well as remedial treatments with minimal intervention approach. This approach is guided by interdisciplinary research to ensure the paintings' long-term protection and integrity.

The programme was established and led by international experts Lisa Shekede and Stephen Rickerby, in collaboration with a Georgian wall painting conservation team.

Since April 2023, the conservation team has been engaged in non-invasive and invasive investigations, monitoring of wall paintings, salt activity, and environmental conditions. They have been developing remedial treatment strategies and methodologies to preserve the Gelati Monastery Complex, a UNESCO World Heritage site.

In addition, the Gelati Wall Painting Conservation Programme incorporates educational components to enhance conservation practices in Georgia and provide training for local professionals.

The Gelati Wall Painting Conservation Team



More information about Gelati Rehabilitation programme
<https://gelatirehabilitation.ge/ka/painting>

Research and Educational Programme context:

Prior to the Gelati programme, since the end of 2019, current members of the Gelati Wall Painting Conservation team have been spearheading a series of long-term research projects and educational workshops within the framework of the Research and Educational Programme in Cultural Heritage Conservation in Georgia. So far, the four projects have been undertaken:

- **Project N1: Research into Medieval Gaji Plasters and Principles for Developing Compatible Conservation Materials (12 months, 2019/20):** this project focused on studying traditional gaji plaster compositions used in medieval Georgian wall paintings to develop conservation materials that are compatible with historic plasters. Collaboration between Tbilisi State Academy of Art, Technical University of Georgia, Ltd Geoengineering, Ltd Conservation Centre of Fine Art, University College London (Joshua Hill), RICKERBY & SHEKEDE; Funded by the International Education Center Alumni Association (Georgia), Grant holder: Mariam Sagaradze
- **Project N2: Salts and Environmental Investigation and Monitoring, International Workshop in Conservation of Cultural Heritage (8 months, 2023):** This project explored the impact of environmental factors, including salts, on cultural heritage sites. It introduced advanced investigation and monitoring techniques to assess these factors and develop strategies to mitigate deterioration. The workshop emphasized practical methods for identifying and managing environmental data and risks to preserve cultural heritage effectively. Collaboration between experts from The Getty Conservation Institute (Vincent Beltran, Wendy Rose, USA), the Nottingham Trent University (Joshua Hill, UK), University of Amsterdam (Jorien Duivenvoorden, NL), Tbilisi State Academy of Art (Mariam Sagaradze, Nutsa Papiashvili, Asmat Tkeshelashvili, Tamar Liluashvili); Funded by the International Education Center Alumni Association (Georgia). Grant holder: Mariam Sagaradze.
- **Project N3: Georgian Immovable Cultural Heritage and Conservation Workshop (6 months, 2023/24):** this workshop provided participants with theoretical and practical training in conserving Georgian immovable cultural heritage sites. Collaboration between Tbilisi State Academy of Art (Mariam Sagaradze, Nutsa Papiashvili, Asmat Tkeshelashvili) and the Estonian Academy of Art (Varje Õunapuu, Hilikka Hiop, Anneli Randla, Merike Kallas, Maris Veeremäe); Funder: Erasmus+
- **Project N4: International Workshop in Cultural Heritage Conservation: Multispectral Imaging and 3D Photogrammetric Monitoring in Wall Painting Conservation (5 months, 2024):** This project explores cutting-edge technologies, such as technical imaging and 3D photogrammetry, to monitor and investigate wall paintings. Collaboration between: Gelati Rehabilitation Committee (Patriarchate of Georgia), Estonian Academy of Art (Estonia); Joshua Hill (London National Gallery, UK), Wendy Rose (The Getty consultant, USA); Funded by the International Education Center (Georgia). Grant holder: Mariam Sagaradze.

See following page for the programme details.

Programme aims

The international educational and research programme contributes towards development of cultural heritage conservation field in Georgia.

The programme helps to address the current challenges in research, treatment and monitoring of cultural heritage monuments in Georgia.

The programme assists in enhancing the qualifications of local personnel working in wall painting conservation.

The programme enhances long-term international professional relationships between local (Georgian) and international experts and institutions from UK, USA, EU.

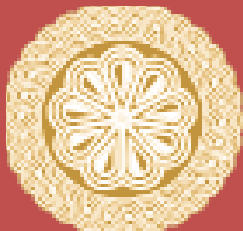
Objectives of the Project N4

- Providing training for Georgian wall painting experts and representatives from partner institutions in multispectral imaging and 3D photogrammetric monitoring
- Non-invasive investigation of the technology and condition of wall paintings at the Gelati Monastery Complex, a UNESCO World Heritage site, using multispectral imaging techniques.
- Development of the 3D photogrammetric monitoring system for the wall paintings at the Gelati Monastery Complex, a UNESCO World Heritage site. The system will monitor salt activity, condition phenomena and treatment effectiveness on the wall painting surface.
- Upgrading and acquiring additional technical equipment for wall painting conservation, enabling local experts to conduct investigations and monitoring of wall paintings not only at Gelati but also at other cultural heritage sites.

FUNDING AND SUPPORTING ORGANIZATIONS



Host organization:
Gelati Rehabilitation Committee



გელათის რეაბილიტაციის კომიტეტი
GELATI REHABILITATION COMMITTEE



Guest organization/ co-organiser:
Estonian Academy of Art



Funder:
LEPL International Education Center of Georgia



LEPL INTERNATIONAL EDUCATION
CENTER OF GEORGIA

PROJECT MANAGEMENT TEAM



MARIAM SAGARADZE

Head of the project/Grant holder;
Co-supervisor of Gelati wall painting
conservation programme



NINO KOBERIDZE

Project manager;
Freelance conservator/Gelati wall
painting monitoring programme
assistant



**ASMAT
TKESHELASHVILI**

Project manager;
Freelance conservator and paper
conservator at Tbilisi State Academy of
Art

Workshop focused on:

- Developing 3D photogrammetric imaging skills for monitoring cultural heritage monuments.
- Developing multispectral imaging skills for the non-invasive investigation of the technology and condition of paintings.
- Familiarizing with the processing of multispectral imaging (MSI) and 3D photogrammetric images.
- Contributing to the wall painting conservation research programme at the Gelati Monastery Complex.

CORE CONTENT

The workshop provided theoretical and practical sessions on the following themes:



Topic 1: 3D Photogrammetric monitoring for wall paintings



Topic 2: Multispectral imaging (MSI) for wall paintings

Practical and theoretical sessions led by international experts:

- Wendy Rose (USA)
- Joshua Hill (UK)
- Andres Uueni (EST)

The project provided:

- Reading materials
- Software for processing multispectral and 3D images
- Imaging equipment for MSI and 3D photogrammetry for in-situ use

Workshop Process: Introduction to the Gelati Monastery Complex



Opening ceremony At the Gelati Academy



Workshop Process: Introduction to Gelati Monastery Complex



Gelati, Main church, Interior of South-West chapel



Gelati, Main church, Interior of the North chapel



Gelati, Exterior of the Main church,

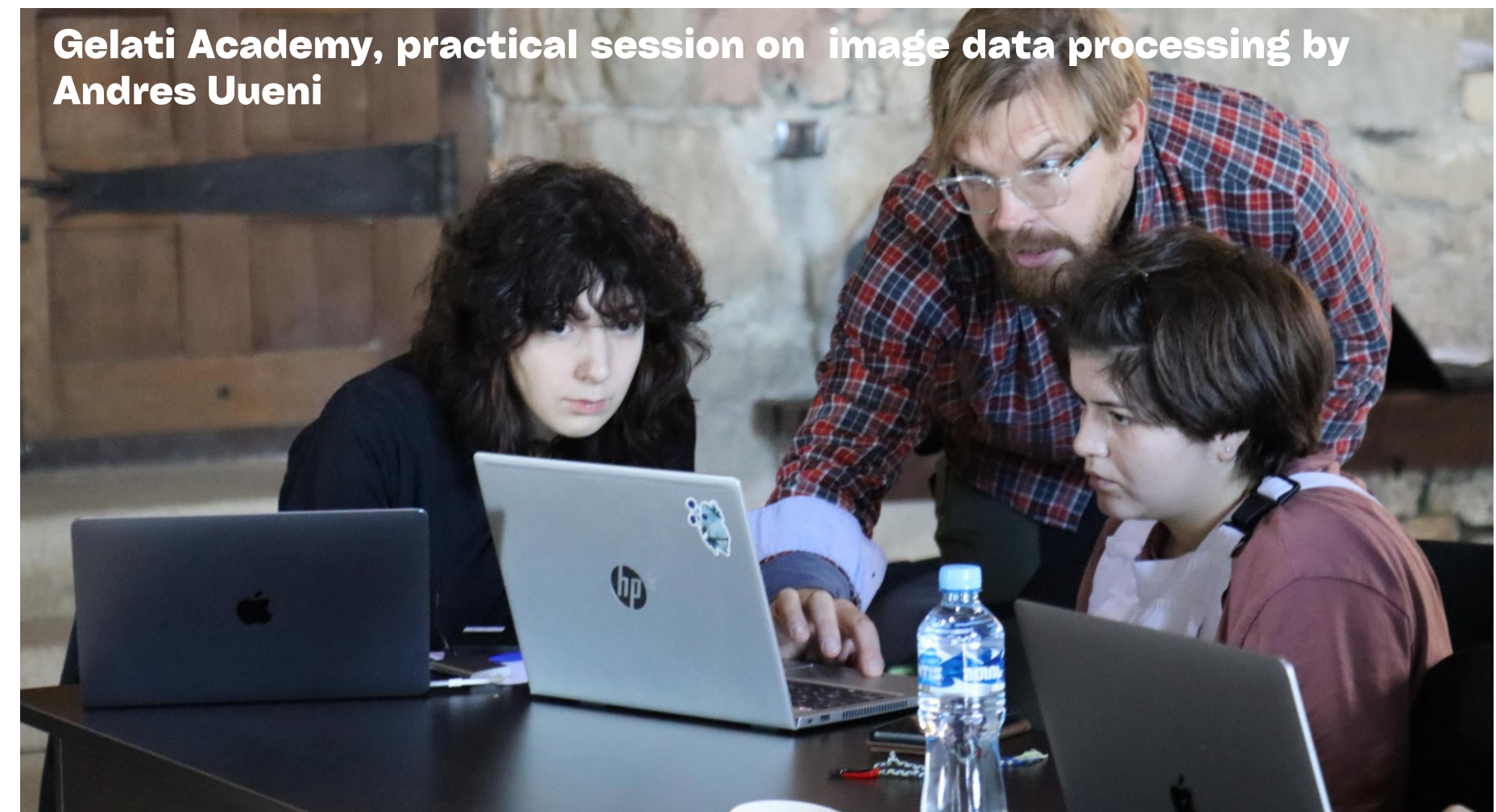
Workshop Process: Multispectral imaging (MSI) and 3D photogrammetry for wall paintings

Andres Uueni (EST), Head of the MUKOLA Laboratory at the Estonian Academy of Arts, has delivered lectures on imaging techniques in the cultural heritage field, with a focus on 3D photogrammetry and reflectance transformation imaging for technical investigations. Uueni actively participated in practical sessions as a mentor. He introduced and demonstrated 3D capturing techniques utilizing visible, ultraviolet, and infrared light. His sessions also provided in-depth knowledge on data processing and analysis.



Gelati, Main church, North-East chapel, practical session of imaging by Andres Uueni

Gelati Academy, practical session on image data processing by Andres Uueni



Gelati Academy, theoretical session on technical imaging by Andres Uueni



Workshop Process: 3D photogrammetric monitoring for wall paintings

Wendy Rose (USA) is a wall painting conservator specializing in photogrammetric documentation. She serves as a consultant for the Getty Conservation Institute (GCI) and the Smithsonian American Art Museum (SAAM).

Rose has delivered both theoretical and practical teaching sessions on 3D photogrammetric monitoring techniques. Her lectures introduce 3D photogrammetry as an innovative and effective digital monitoring method for in-situ wall paintings, a technique she developed during her MA research.

Wendy played a key role in identifying and procuring technical equipment for the Gelati Project.

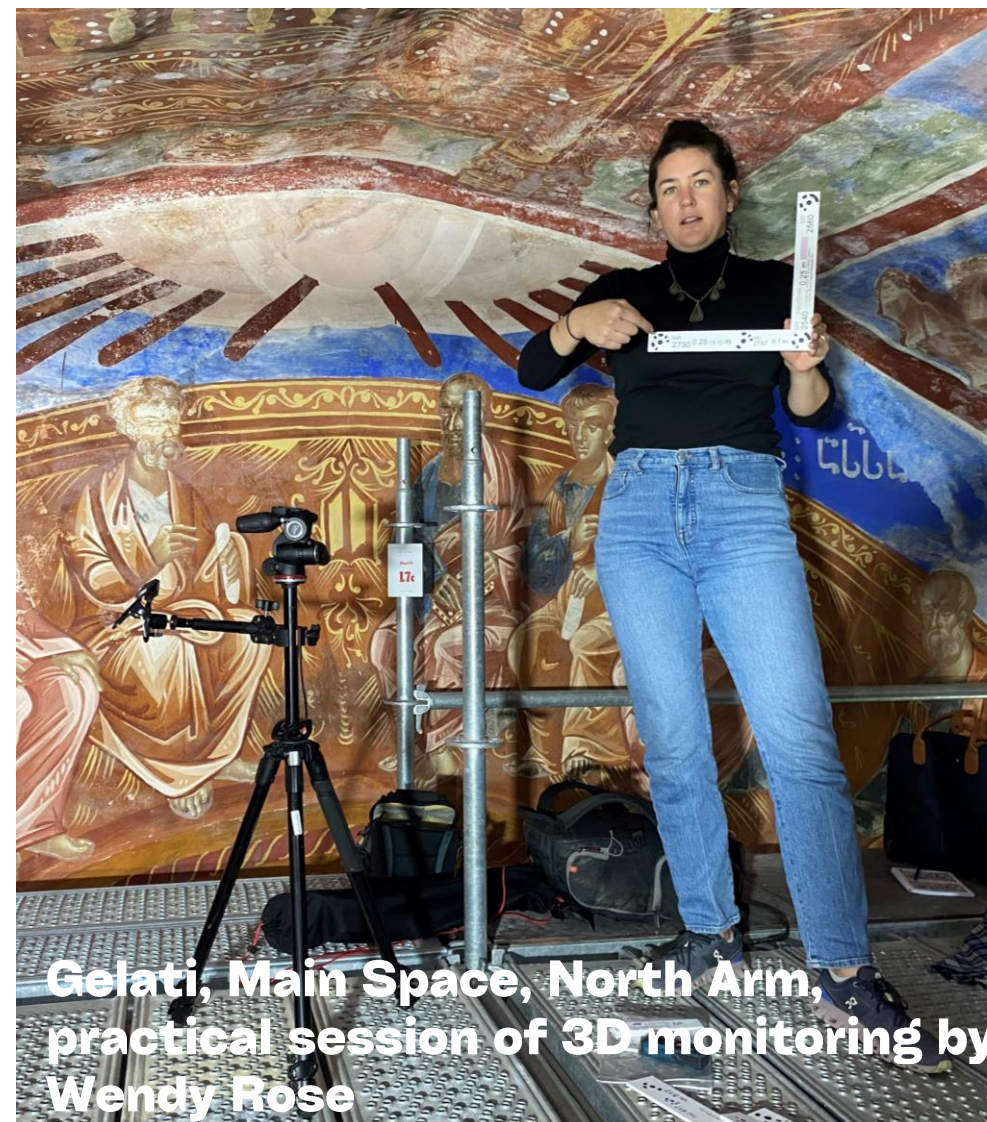
She also led hands-on sessions covering 3D photogrammetric imaging, capturing monitoring areas, processing photogrammetric data, conducting comparisons, and recapture processes.



**Gelati Academy, Theoretical lectures
and practical session on data
processing by Wendy Rose**



**Gelati, Main Space, West Arm, practical
session of 3D monitoring by Wendy Rose**



**Gelati, Main Space, North Arm,
practical session of 3D monitoring by
Wendy Rose**



Workshop Process:

Multispectral imaging (MSI) for wall paintings

Joshua Hill (UK) is a wall painting conservator and conservation scientist, currently serving as the Aldama Scientific Fellow at the National Gallery, London, and a Visiting Fellow at Nottingham Trent University.

He has delivered theoretical lectures on technical imaging and conducted practical sessions focusing on in-situ image capturing using visible, ultraviolet and infrared lights, image data processing, and interpretation.

As part of a broader project, Hill undertook a comprehensive study of the equipment market, identifying and acquiring the specialized items necessary for technical imaging. This effort not only enhanced the workshops but also contributed significantly to the investigation of the Gelati wall painting project.



Gelati, Main space, South arm, practical session of technical imaging by Joshua Hill



Gelati, Main space, North arm, practical session of technical imaging by Joshua Hill



Gelati Academy, Theoretical lectures and practical session on data processing by Joshua Hill

Workshop organizers, mentors, participants:

Organisers and expert attendees from Georgia and Estonia (EKA):

Mariam Sagaradze
Asmat Tkeshelashvili
Nino Koberidze
Hilkka Hiip
Anneli Randla
Merike Kallas
Maris Veeremäe

Mentors from USA, EU, UK:

Wendy Rose
Andres Uueni
Joshua Hill

10 certified participants from Georgia and Estonia:

Sophio Mikaberidze
Nana Khuskivadze
Eter Toloraia
Ela Saakian
Nino Koberidze
Salome Markozia
Sesili Sordia
Varje Õunapuu
Egert Lass
Rasmus Kristofer Randla

Organisers from host institution - Gelati
Rehabilitation Committee:
Father Kirion
Mikheil Gaprindashvili

Representatives from funding institution -
International Education
Center of Georgia:
Meri Tinikashvili
Ketevan Chakhnashvili



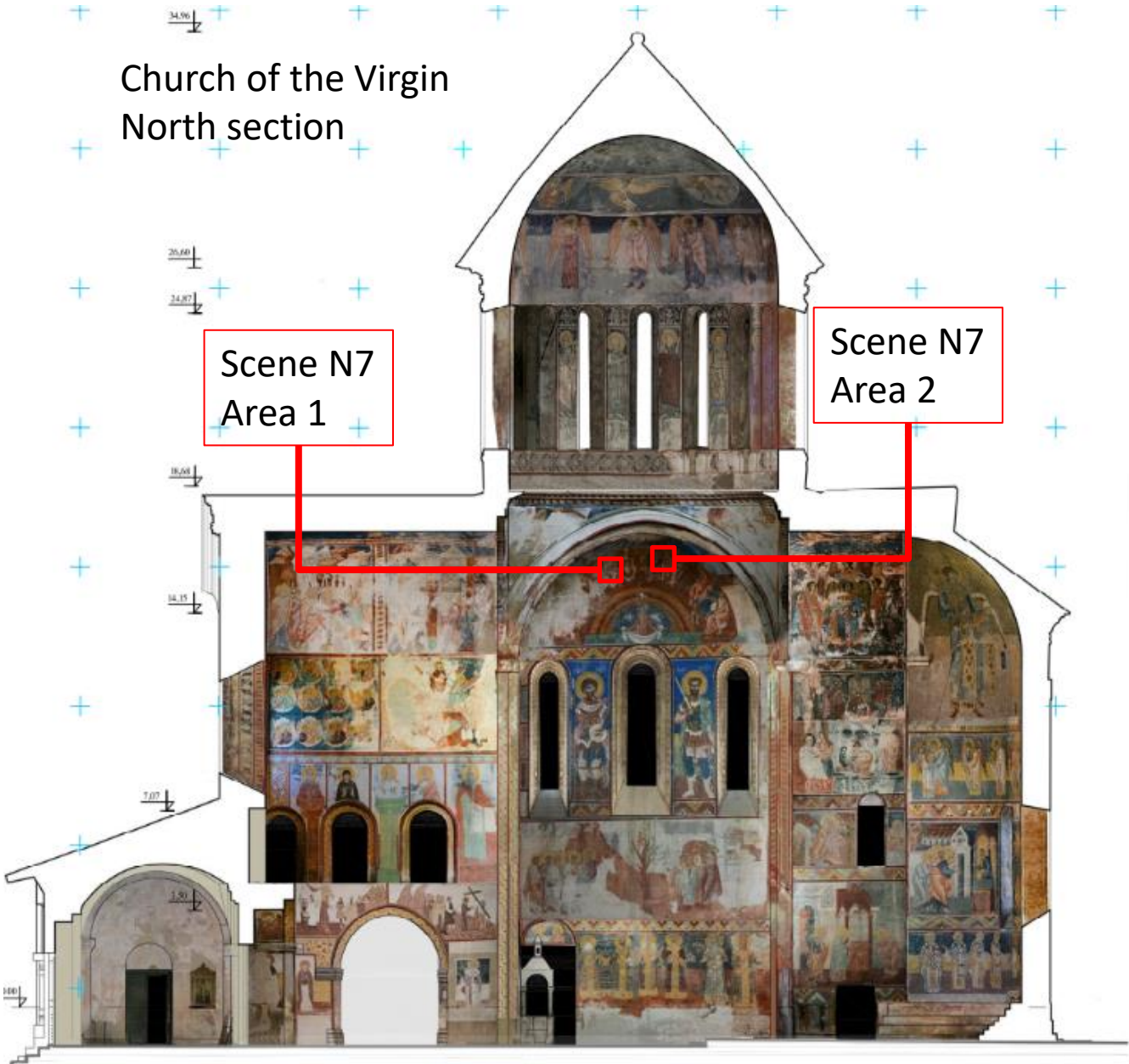
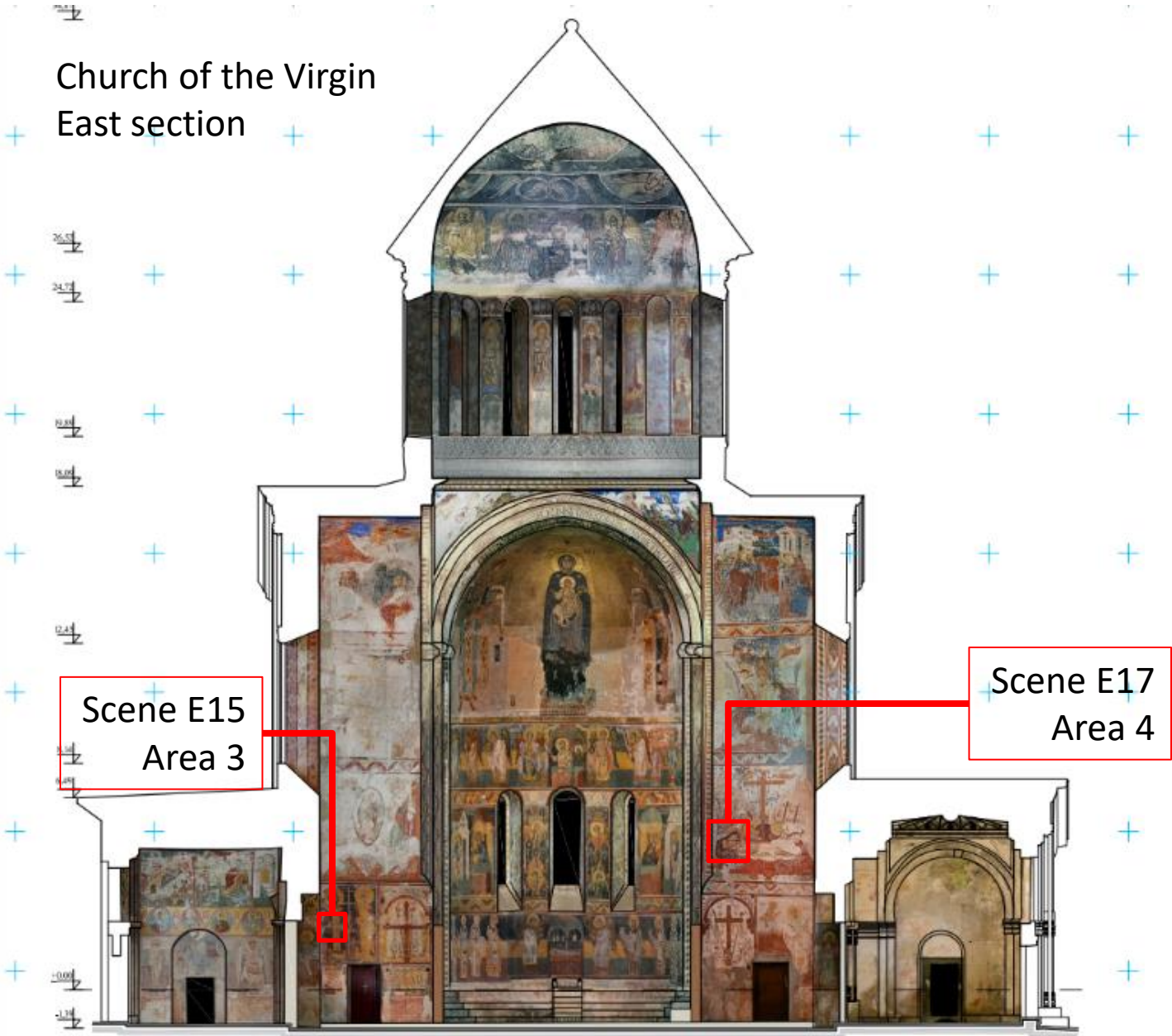
Research and Produced Data

Technical imaging (IR, UV, VIS)

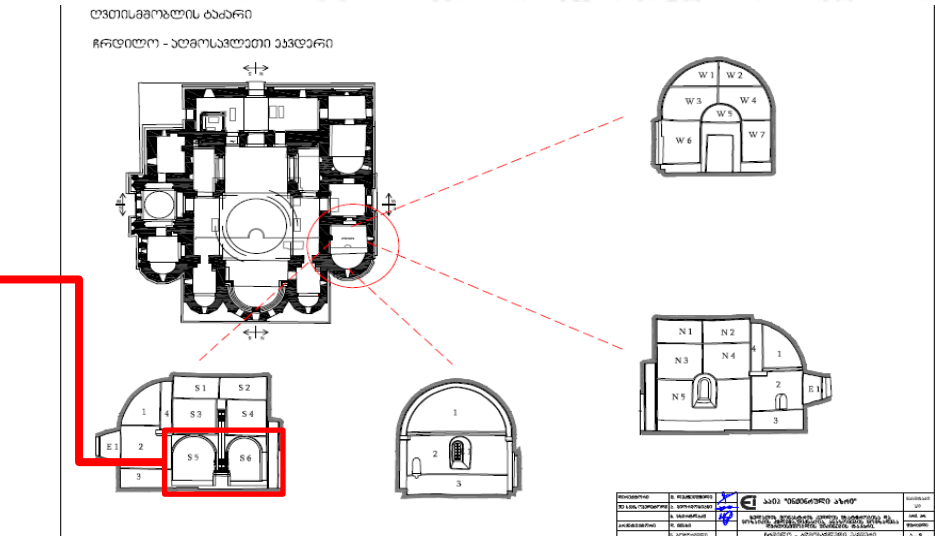
Within the project scope, we have developed an investigation strategy for technical imaging, defined research questions, and selected initial four areas based on specific criteria.

List of selected areas:

1. The Church of the Virgin Mary, Main Space, North Arm, North wall, N7, Area 1
2. The Church of the Virgin Mary, Main Space, North Arm, North wall, N7, Area 2
3. The Church of the Virgin Mary, Main Space, North Arm, East Wall, E17, Area 3
4. The Church of the Virgin Mary, Main Space, South Arm, East Wall, E15, Area 4
5. The Church of the Virgin Mary, the North-East Chapel, South Wall, Lower Tier, Area 5



The Church of the Virgin Mary, the North-East Chapel, South Wall, Area 5



Research and Produced Data

Multispectral/technical imaging is a non-invasive imaging technique used to indicate and differentiate between original and non-original materials in artworks, such as paintings or murals. It is particularly useful for mapping the distribution of these materials, aiding in conservation, restoration, and condition assessment.

Key Features of technical imaging:

- Use of Different Spectral Ranges

Multispectral imaging involves capturing images across different ranges of the electromagnetic spectrum, including:

- Infrared (IR)
- Visible light
- Ultraviolet (UV)

Each spectrum provides unique information about the luminescent and reflective properties of materials, such as pigments, binders, and other organic substances.

Characterization of Materials

This technique is employed to:

- Identify differences between original and non-original materials.
- Visualize the distribution of pigments and organic substances on the surface.
- Distinguish between various layers of paintings, including overpaints, restorations, and retouching.
- By analysing how different wavelengths interact with the materials, conservators can map out the composition of the artwork.



Research and Produced Data

Infrared Light for Sub-Surface Investigation

Infrared light, particularly at longer wavelengths, can penetrate beneath the surface layers of the artwork. This allows the detection of:

- ✓ Under-drawings or sketches beneath the paint.
- ✓ Hidden features or inscriptions that may not be visible to the naked eye.
- ✓ Preparation techniques, such as those used in Gelati wall paintings, which may include details about the materials or methods employed in the base layers.

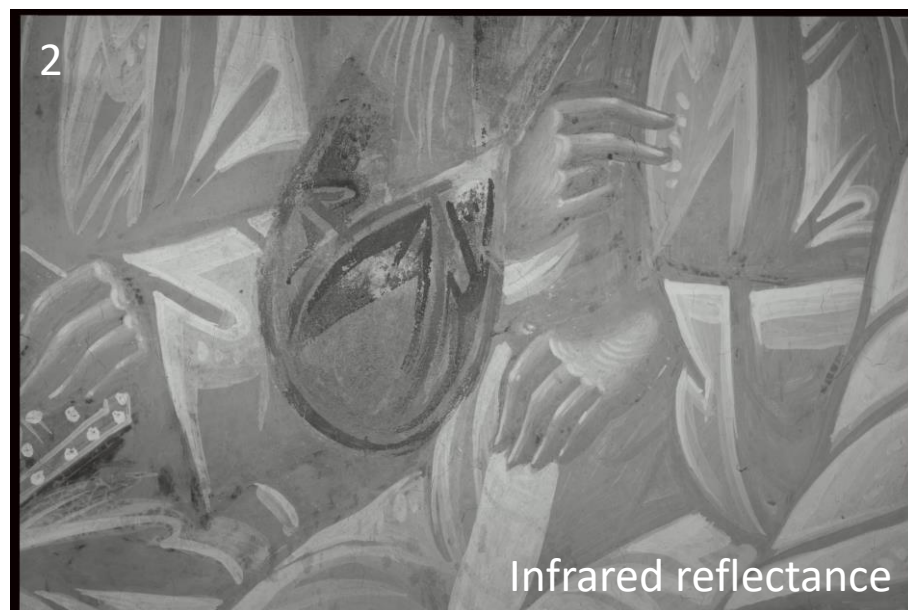
Ultraviolet Light for Surface Analysis

UV light highlights fluorescence and surface properties of materials, revealing:

- Varnish layers and degradation.
- Organic substances like resins, glazes, and binders.
- Restoration areas and repaintings (non-original parts of the painting).

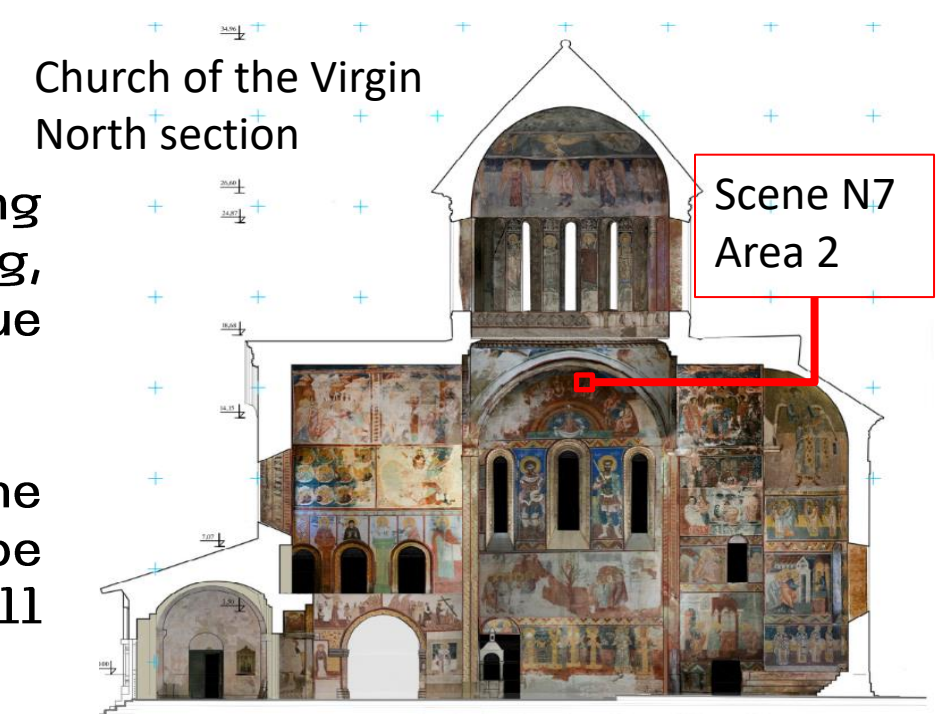
The Church of the Virgin Mary, Main Space, North Arm, North wall, N7, Area 2

Area N2 was chosen to distinguish and identify the blue pigments used in the figure's drapery.



Through multispectral imaging and subsequent data processing, three distinct types of blue pigments have been indicated.

The finding of the investigations will be integrated into the Gelati Wall Painting Research report.



Research and Produced Data

Combined Analysis for Comprehensive Insights: By combining infrared, visible, and ultraviolet imaging, multispectral photography can differentiate between materials that may appear identical in the visible spectrum but have distinct characteristics under other wavelengths. This is critical for identifying original materials versus modern additions or repaintings, aiding in the accurate assessment of the artwork's authenticity and condition.

Research questions for the multispectral imaging within the programme:

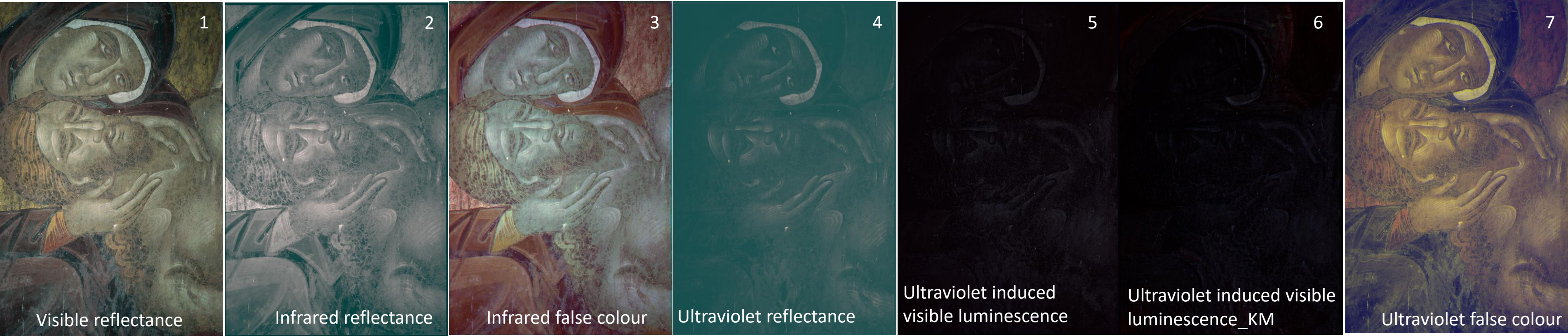
Investigation of the original technology:

- Indication and distribution of different type of blue pigments
- Indication of the use of lead – tin yellow
- Indication of the use of organic colorants
- Revealing inscriptions

Investigation of the condition

- Biological activity
- Previous intervention materials

The Church of the Virgin Mary, Main Space, South Arm, East Wall, E15, Area 4 – chosen for possible use of lead – tin yellow



The finding of the investigations will be integrated into the Gelati Wall Painting Research report.

Research and Produced Data

3D Photogrammetric Monitoring:

Within the project scope, Wendy Rose and Gelati wall painting team have developed a monitoring strategy for 3D photogrammetric monitoring, defined monitoring questions, and selected initial five areas based on specific criteria.

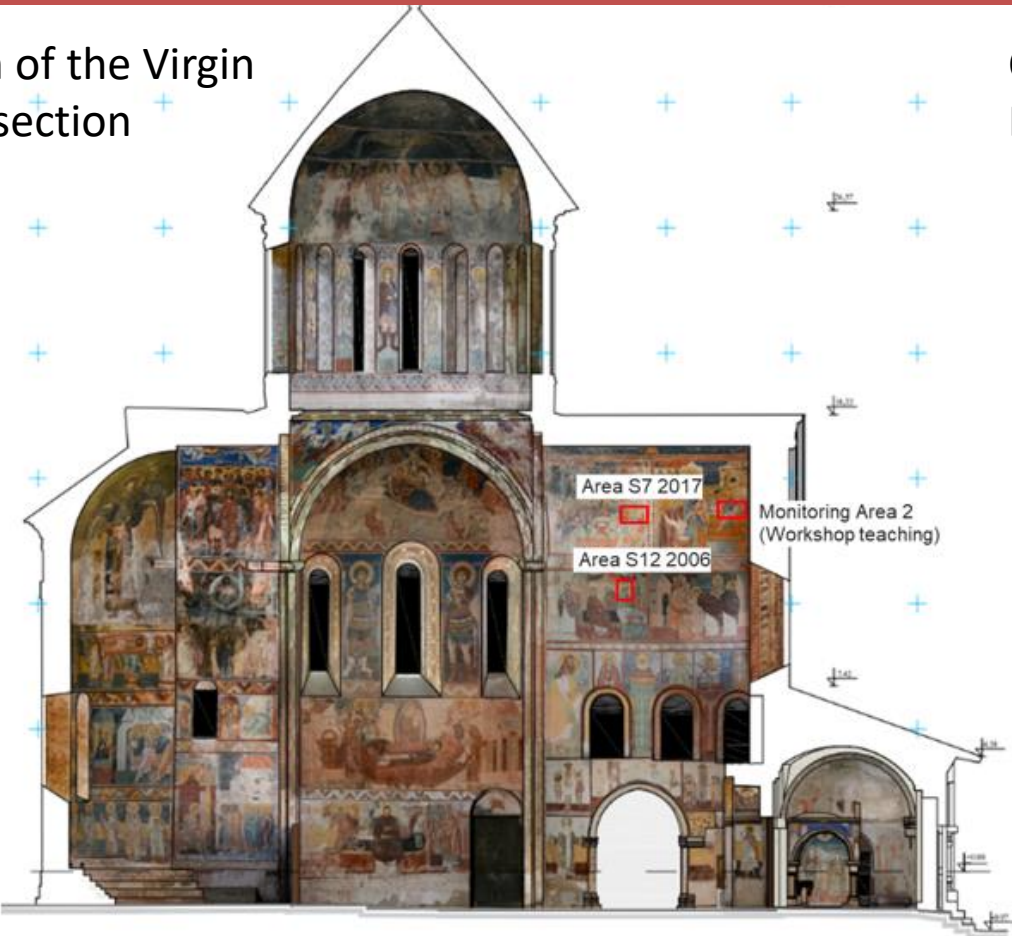
List of selected areas:

1. The Church of the Virgin Mary, Main Space, North Arm, North wall, N7, Area N7 2122
2. The Church of the Virgin Mary, Main Space, North Arm, North wall, N12, Area N12 1300
3. The Church of the Virgin Mary, Main Space, North Arm, East Wall, E5, Area 5 2026
4. The Church of the Virgin Mary, Main Space, West Arm, North Wall, N6, Area N6 2023
5. The Church of the Virgin Mary, Main Space, West Arm, South Wall, S7, Area S7 2017
6. The Church of the Virgin Mary, Main Space, West Arm, South Wall, S12, Area S12 2006
7. The Church of the Virgin Mary, Main Space, West Arm, South Wall, S8, Area S8

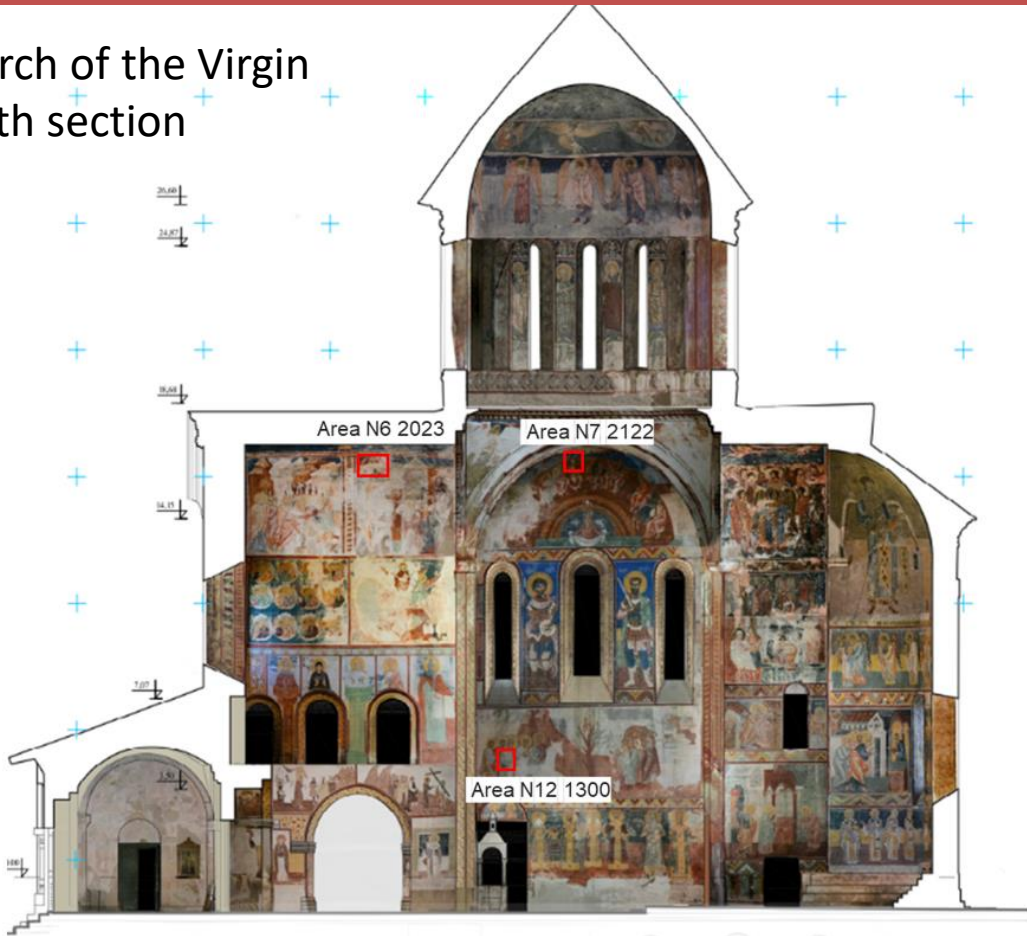


Wendy Rose and Mariam Sagardze

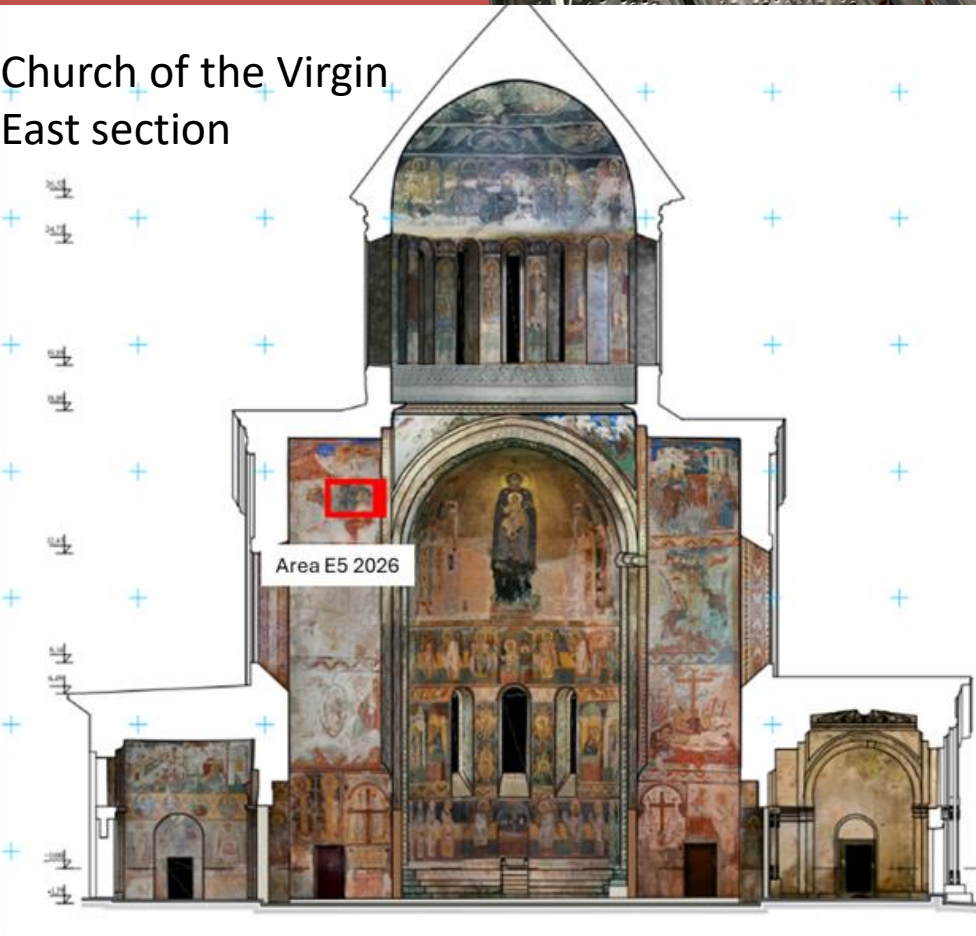
Church of the Virgin
South section



Church of the Virgin
North section



Church of the Virgin
East section



Research and Produced Data

3D Photogrammetric Monitoring:

Monitoring Purpose:

Gather quantitatively and qualitative data on

- The activity rate, scale and distribution of the condition phenomena
 - ✓ Salt activity
 - ✓ Biological activity
 - ✓ Paint Flaking
- Treatment efficiency
- Previous intervention impact on wall painting condition



Wendy Rose undertaking 3D capturing of wall painting at the Church of the Virgin Mary, main space, north arm, east Wall, Area 5 2026

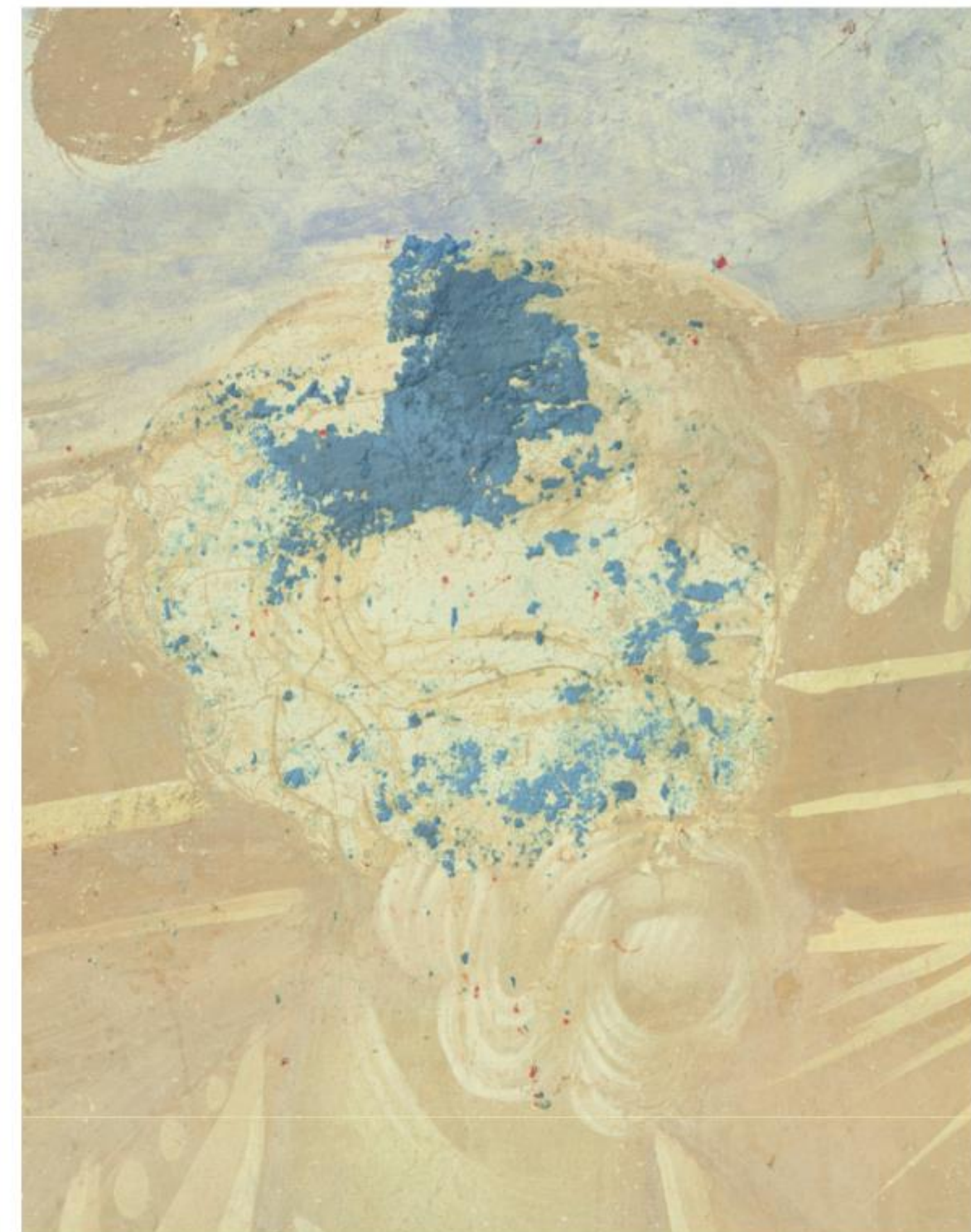
As part of the project, we monitored the condition of the painting before and after salt removal in the Church of the Virgin Mary, Main Space, North Arm, North Wall, Area N7 2122. The monitoring method provided data on the changes, particularly the scale and distribution of the removed salt layer.

Monitoring is on-going and data will be integrated into the Gelati Wall Painting monitoring programme report.

Change in meters
(m)

0.0005

-0.0005



0 0.05 0.1 m

Research and Produced Data

The documentation produced during the project is freely accessible to participants and involved institutions and includes the following:

Guidelines and Protocols

Technical Imaging: Using IR, UV, and visible light.

Image Processing: Instructions for processing technical images in the Nip2 program.

3D Photogrammetric Monitoring: Protocols for capturing and monitoring using photogrammetry.

Data Handling: Guidelines for data processing and storage.

Equipment Overview

A comprehensive list of available equipment.

Teaching Materials:

- ✓ The teaching resources cover the following topics: Multispectral Imaging
- ✓ Reflectance Transformation Imaging (RTI)
- ✓ 3D Photogrammetric Imaging and Monitoring

3D Monitoring Capture Protocol

Gelati Monastery

This document aims to facilitate consistent, repeatable photogrammetric capture of the wall paintings in Gelati Monastery. It is important that each capture is undertaken in the same way to reduce variables in the change detection. It is also crucial that special care is taken with the equipment during capture to avoid mechanical damage to the paintings.

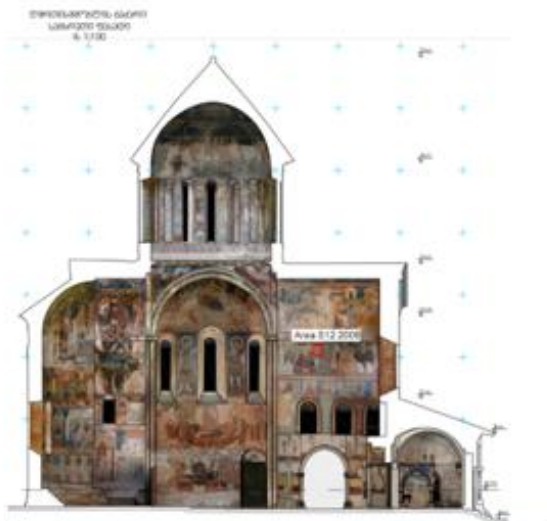
The following camera and lighting equipment should be utilized for each photogrammetric capture in the Church as follows:

Equipment type	Description	Count
Camera		
Camera body	Nikon D610	1
Lens	Nikon NIKKOR AF 50 mm 1:1.8 D	1
SD Card	32 GB SD card	3
Camera battery	Nikon battery	3
Camera battery charger	Nikon battery charger	1
Lighting		
Ring Flash	MF18 Macro RingFlash	1
Ring Flash stepping	Nissin 55mm stepping	1
Filter	Hoya Pro1 digital MC UV (0) 52 mm	1
Filter ring	52mm – 55mm stepping	1

In addition to the camera and lighting equipment, the following tools should be onsite to facilitate capture:

Measurement	
Leica Distometer	1
Photogrammetric scale bar 25cm (either right angle bar or straight bar)	1
ColorChecker	1
Tripod to attach selfie stick with scale bar	1
Super Clamp Double Camera Clamp	1
114cm Invisible Selfie Stick	1
1/4"-20 Female Screw Double Thread Adapter for Extension Arm	1
Tripod Clip Clamp Mount	1

S12 2006:



- Monitoring Rationale:
- Critical Risk Zone: This area is classified as critical due to its vulnerability to material loss.
 - Historical Context: Research indicates that paint loss was already evident prior to 2017.
 - Current Condition: Remaining paint layers are detached from the plaster, leading to significant flaking.
 - Monitoring Objectives:
 - Assess whether flaking is ongoing.
 - Evaluate the response of flaking to environmental fluctuations.
 - Determine the overall risk of further loss.



Capture conditions	
Camera	Nikon D610
Number of Images	60
ISO	100
Aperture	f/11
Shutter speed	1/125
Focal length	50mm
Lighting	MF-18 Ringflash
Flash power	¼ flash power manual
Distance from subject	0.7m
GSD	0.08mm/pixel

Above is provided examples of the produced data:

On the left - 3D Monitoring Capture Protocol created by Wendy Rose.

On the right - Monitoring area Characterisation and specifics created by Wendy Rose in collaboration with Gelati Wall painting team members.

Project outcomes

- **Development of Cultural Heritage Conservation in Georgia:** The international educational and research programme has significantly contributed to advancing the field of cultural heritage conservation in Georgia, addressing critical challenges in research, treatment, and monitoring of cultural heritage monuments.
- **Enhanced Qualifications for Local Experts:** The programme has played a vital role in enhancing the qualifications of Georgian personnel working in wall painting conservation, fostering expertise and professional growth.
- **Strengthened International Collaboration:** The programme has successfully fostered long-term professional relationships between Georgian experts and international institutions and specialists from the UK, USA, and the EU, promoting collaborative advancements in cultural heritage conservation.
- **Regional Development in Education and Tourism:** The project has contributed to regional development by strengthening education in the field of cultural heritage conservation and promoting tourism at the Gelati Monastery Complex, a UNESCO World Heritage site.
- **Reviving Gelati Academy's Educational Legacy:** This initiative continued the historical tradition of Gelati Academy as a center of education and learning, linking its rich past to contemporary advancements in cultural heritage research and conservation.



Project outcomes

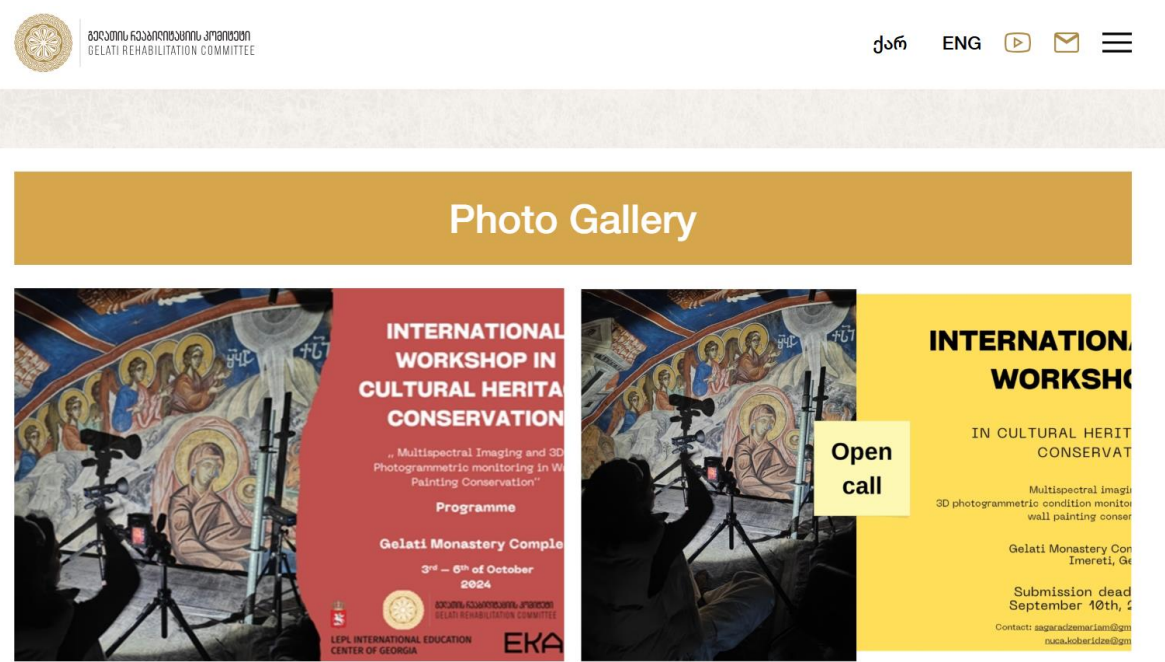
- **Training Delivered:** Comprehensive training sessions were successfully conducted for Georgian wall painting experts and representatives from partner institutions, equipping them with practical knowledge and skills in multispectral imaging and 3D photogrammetric monitoring techniques.
- **Non-Invasive Investigations enriched:** The technology and condition of the wall paintings at the Gelati Monastery Complex, a UNESCO World Heritage site, were additionally investigated using advanced multispectral imaging techniques, providing critical insights without causing any damage.
- **3D Photogrammetric Monitoring System Established:** A robust 3D photogrammetric monitoring system was developed and implemented for the wall paintings at the Gelati Monastery Complex. This system will track salt activity, surface condition phenomena, and the effectiveness of conservation treatments.
- **Technical Equipment Enhanced:** Additional technical equipment for wall painting conservation was successfully upgraded and acquired. These resources now empower local experts to independently conduct investigations and monitor wall paintings at Gelati and other cultural heritage sites.



Media and Public Engagement

The Research and Education Programme received significant media coverage, showcasing its impact and outreach efforts. The programme was featured on three television channels, bringing attention to its investigation and monitoring techniques and findings. Additionally, information about the programme was disseminated through the Gelati Rehabilitation Committee website, the Tbilisi State Academy of Arts website, and various social media platforms.

These efforts garnered substantial public interest, drawing attention from both the professional community and the general audience, further amplifying the importance of cultural heritage conservation and education.



<https://gelatirehabilitation.ge/en/news/view/46>



გელათის სამონასტრო კომპლექსში კედლის მხატვრობის კონსერვაციის სამუშაოები გრძელდება

[www.youtube.com](https://www.youtube.com/watch?v=io1cMID6V6U)

<https://www.youtube.com/watch?v=io1cMID6V6U>



გელათის სამონასტრო კომპლექსის გადარჩენის სამუშაოები გრძელდება...

<https://rustavi2.ge/ka/news/293745>



ექსპერტები გელათის სამონასტრო კომპლექსში

<https://www.youtube.com/watch?v=g85hNhfmsMI>