Gelati Monastery Complex

The Church of the Nativity of the Virgin Mary

Main Space

Summary of the Survey of the Wall Paintings

2024

Stakeholder: Gelati Rehabilitation Temporary Committee

Summary

Contents

Context

The Gelati Monastery Complex is a masterpiece of medieval Georgian architecture and an important cultural and religious landmark. Located in the Imereti region of western Georgia, it embodies the spirit of the Georgian Golden Age. The complex was established in 1106 by King David IV, famously known as David the Builder.

At the heart of the monastery lies the Church of the Nativity of the Virgin Mary, the central cathedral of Gelati. Renowned for its architectural sophistication and multi-layered paintings spanning the 12th to 18th centuries, the cathedral serves not only as a religious space but also as a treasury of Georgian history, culture, art, and craftsmanship.

The cathedral's main space is flanked by northern, southern, and western chapels and entrances, all adorned with interior decorations. Among the earliest and most significant artworks is the 12th-century mosaic in the altar conch of the main space, a testament to the artistic excellence of the period.

The majority of the wall paintings in all four arms and dome of the main space date to the 16th and 17th centuries. Following the devastating fire of 1510, Gelati underwent a gradual process of restoration. The initial repainting took place between the 1520s and 1550s under the patronage of King Bagrat III of Imereti and Bishop Melkhizedek Sakvarelidze. Further restoration occurred in the 1560s–1570s, supported by Giorgi II of Imereti. Other sections, such as the lower registers of the arms, were painted in the 17th century during the reign of Alexander III of Imereti and Catholicos Zacharias Kvariani (circa 1657–1660). Fragments from the 17th century are also visible in other parts of the cathedral. In a late manifestation of artistic intervention, 18th-century repainting was carried out over 16th-century painting in the bema of the eastern arm of the main space. The two layers exhibit significant differences in both technology and style, distinguishing the later addition from the original painting.

The dating of this extraordinary combination of paintings relies on research, including the analysis of historic sources, wall inscriptions, subject matter, stylistic features and critically, on distinctive features of original technology. Their survival underscores the importance of the Church of the Nativity of the Virgin Mary as a vital repository of Georgian ecclesiastical art and history. However, further technical and art historical research is necessary to refine and expand the current understanding of these paintings.

General history and physical history

General history

From the 12th to the 15th centuries, the Gelati Monastery enjoyed complete autonomy, answering only to the supreme authority of the king. Even the Catholicos-Patriarch of Georgia had no administrative power within the monastery, apart from the blessing of priests. The king maintained a personal representative at Gelati, and the senior nuns and abbots were considered members of the royal court.

However, from the second half of the 13th century to the 15th century, the political and economic decline of Georgia—marked by the Mongol and Timurid invasions as well as intensified feudal conflicts—disrupted the monastery's economic and cultural life. Partial restoration of its former prominence was achieved under King Giorgi V the Brilliant.

Following the political collapse of Georgia in the late 15th century, the Gelati Monastery came under the control of the kings of Western Georgia. On November 23, 1510, it was burned by the invading Ottoman army. Kings Bagrat III and Giorgi II of Imereti undertook extensive restoration and reconstruction efforts, including repairing and repainting the churches, rebuilding the destroyed refectories, and donating new estates to the monastery. Bagrat III earned the title "Rebuilder of Gelati" for his efforts, supported by Bishop Melkisedek Sakvarelidze and Catholicos-Patriarch Evdemon Chkhetidze.

In the 1520s, Bagrat III established an episcopal see at Gelati, enhancing its political, moral, and economic stature. By the late 16th century, the residence of the Catholicos-Patriarch of Western Georgia was moved from Bichvinta to Gelati. During the 18th century, further large-scale restorations were carried out by George VI, Alexander V, Solomon I, Solomon II, and the bishops of Gelati. During the reign of King Solomon I of Imereti (1752–1784), the Cathedral was covered with iron sheets brought from Russia, and a new stone floor was laid inside. However, after the abolition of the Kingdom of Imereti by the Russian Empire in 1810, Gelati Monastery lost its ecclesiastical independence and was under the Russian Church rule.

In 1837, due to the visit of Russian Emperor Nicholas I, some repair works were undertaken in the monastery. In the 1840s, further roof rehabilitation work was carried out on the Church of the Virgin. In the 1860s, new windows were installed in the main church, and later, in the 1880s, minor repairs and paint work were undertaken on the roof. In 1923, the monastery was closed and became a branch of the Kutaisi State Historical and Ethnographic Museum.

Conservation history

Modern conservation and restoration efforts at Gelati span nearly a century. In 1952–1954, Rusudan Mepisashvili and Vakhtang Tsintsadze measured the monastery buildings[1], while in 1953, artist-restorer Shalva Abramishvili cleaned and stabilized the paintings in the narthex of the Cathedral of the Virgin Mary. One fragment, at risk of collapse, was transferred to the Kutaisi Historical-Ethnographic Museum[2]. Abramishvili also carried out emergency restoration on the murals of the South-Eastern chapel, South chapel, and North-East chapel[3]. The pioneer Georgian artist-restorer Karlo Bakuradze, along with Shalva Abramishvili, was also involved in conservation endeavours in the 1950s[4].

During the 1970s, the tin roof and windows of the main cathedral were renewed, and drainage systems were installed[5]. From 1979 to 1981, conservation work focused on the paintings in the northern chapels and entrance, including uncovering the early 13th-century mural layer in the South-West Chapel, and 16th century paintings from Northen Entrance. This work was led by a team of restorers headed by Amiran Goglidze[6].

From 1984 to 1989, the mosaic in the bema of the eastern arm of the main space was treated, and conservation of the paintings here was overseen by artist-restorer Karlo Bakuradze (Vladimir Gurgenadze, Guram Cheishvili and Amiran Goglidze were also part of the wall painting conservation team)[7]. Additional restoration efforts from 1980s to 1990 included stabilizing the murals in the Southern chapels and entrance under the leadership of Vladimir Gurgenadze.

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[1] The documentation describing the works is published in the book: R. Mepisashvili, Architectural Ensemble Gelati, Tbilisi, 1966

[2] T. Virsaladze, Fragments of ancient fresco paintings of the main Gelati temple, Ars Georgiaca, V, Tb., 1959, p. 165. 4.

[3] Archives of the Department of Monuments Protection of Georgia, photographs # 13113-13132/493; # 14382-14411/509

[4] In December 2024, the current wall painting conservation team found an inscribed signature from the 1950s in the interior of the dome on the internal wall of the window frame. The signature is possibly that of K. Bakuradze, written in both Georgian and Russian, along with the year. Further investigations are being made.

[5] 4Archives of the Department of Monuments Protection of Georgia, photographs n# 40578-40588/754; # 39459-39477/746.

[6] Graphic documentation of Northern chapels Entrance, Archival documentation, 1981, National Agency for Cultural Heritage Preservation of Georgia.

[7] L. Khuskivadze, Gelati mosaic, Tbilisi, 2005, p. 9-13.

In the post-Soviet era, particularly in 2003-06[8], a diagnostic study of the wall paintings was conducted, which was followed by the development of a general conservation plan in 2008, approved in 2009 and updated in 2015[9].

Between 2012 and 2013, conservation work was carried out on the wall paintings of the South Entrance and the South-West Chapel, and the roof of the South-West Chapel was repaired[10]. From 2015 to 2019[11], significant restoration efforts included replacing the roofing—metal roofs were replaced with glazed clay tiles and stone slabs (in the case of the North-West Chapel). In 2015, conservation of the paintings in the main dome was undertaken[12]. Additionally, conservation of the façade stones was undertaken[13], and general survey of paintings were undertaken along with 3D scanning[14].

In 2017, water infiltration in the Northern and Southern Entrances provoked new biodeterioration, which was treated locally. However, after completion of the re-roofing works and the stone restoration in 2019, water infiltration reoccurred in the Main Cathedral and in St. George's Church due to defects and failures in the newly installed glazed tiles. The infiltration caused damage to the medieval wall paintings. Investigations revealed that between 2016 and 2019 the issues stemmed from improper roofing methods, poor-quality materials, and the absence of temporary roofing during the rehabilitation process.

In 2019, emergency treatments were carried out in the north arm of the Main Church. To prevent further damage, temporary tin roofs were installed over the cathedral in 2020–2021. Beginning in 2020, gradual monitoring of the condition of the wall paintings commenced, and several emergency treatments were undertaken in March 2021 in the South-West Chapel and the west arm of the main space to address painted plaster failure[15].

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[8] ნ. კუპრაშვილი, გელათის ღვთისმშობლის ტაძრის მოხატულობათა თავისებურებანი (ტექნიკისა და სტილის ურთიერთმიმართება), დისერტაცია, თბ., 2006; N. Kuprashvili, Peculiarities of paintings of the Cathedral of the Virgin of Gelati (relationship of technique and style), Dissertation, tb., 2006

[9] https://gelatirehabilitation.ge/uploads/documents/docs/2015-GEO-gelati-conservation-plan-updated-.pdf

[10] გელათის ღმრთისმშობლის ტაძრის წმ. მარინეს ეგვტერისა და სამხრეთ კარიბჭის ფრესკების გადაუდებელი საკონსერვაციო სამუშაოები' ხელოვნების საერთაშორისო ცენტრი, რესტავრაციის, ხელოვნების ისტორიისა და თეორიის ფაკულტეტი, თბილისის სახელმწიფო სამხატვრო აკადემია, შპს გორსო, შპს იკორთა 2007; დაფინანსება: ამერიკის შეერთებული შტატების საელჩო (2013)

[11] https://gelatirehabilitation.ge/uploads/documents/docs/8888.pdf

[12] გელათის ღვთისმშობლის შობის ტაძრის გუმბათის მოხატულობის გადაუდებელი საკონსერვაციო სამუშაოები, ჯგუფის ხელმძღვანელი ს. რუბაშვილი; ხელოვნების საერთაშორისო ცენტრი, დაფინანსება: ამერიკის შეერთებული შტატების საელჩო (2015)

[13] Documentation uploaded on the website: www.gelatirehabilitation.ge

[14] Under the National Agency for Cultural Heritage Conservation.

[15] https://gelatirehabilitation.ge/uploads/documents/docs/e4513ff319226c80eaf7ecdc6cb97f89.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/58d816cf2d9b9882d294729bf898f423.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/9c900369b53684296f5dc94a61910f8d.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/c27364e700627cef0fe1303cbba0e22a.pdf

In June 2021, the wall paintings were further surveyed, and additional emergency treatments were carried out by a Georgian-Italian team. Technical studies and treatments of the wall paintings, including hygrometric research[16], continued to the close of 2022 under the leadership of *ASSOCIAZIONE GIOVANNI SECCO SUARDO*[17]. In 2022, the roof over the western arm was lifted, and the space beneath it was cleared of filling material by a team headed by Italian Architect Ugo Tonietti and Sara Stefanini C. A temporary tin roof was installed on wooden beams, but these measures proved insufficient to fully protect the monuments from continuing intermittent water infiltration[18].

In February and March 2024, strong winds and heavy rains resulted in further water infiltration on the interior of the Main Church[19]. Temporary fixes were made to seal openings in the windows and roof.

Since 2023, extensive architectural and structural research has been underway, including monitoring and analysis of salts, wall paintings, mosaics, and the overall condition of the complex. These efforts involve collaboration between leading

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https://gelatirehabilitation.ge/uploads/documents/docs/75bf227b17b681a00099328dddda38d0.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2020.09.19_STUDIO-MASSARI-Rapporto-ENG-GEO.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/01a2b55e59fa008bc38e1589c848f273.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/10.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/12.pdf

[16] https://gelatirehabilitation.ge/uploads/documents/docs/2021.12_Alessandro-Massari's-mission-report.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2022.07.04_Alessandro-Massari's-supplementary-note.pdf

[17] https://gelatirehabilitation.ge/uploads/documents/docs/2121212121-d524b4c8b9dc3908de11f9cb8cd7e8c0.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2021.10.20_Secco-Suardo_Centanni's-second-mission-report.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/030303-33400474a8c8e511fe7df30422db17b3.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2021.12_Alessandro-Massari's-mission-report.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/111222333-b26d858c10ef406f66254de72525075c.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2022.05.27-06.03_Marco-Pulieri's-mission-report.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/2022.11.23_Secco-Suardo_Melica's-report-part-II.pdf

[18] See website: www.gelatirehabilitation.ge
[19] https://gelatirehabilitation.ge/uploads/documents/docs/5-6-Tebervlis-stiqia-ecbc607d97d9fcdb6d7055e7f517f4ec.pdf

international and Georgian specialists. Environmental monitoring of the interior and exterior of the complex, initiated in 2020, is ongoing.

In March 2024, a conservation programme was begun which had as its main aims the development of a remedial intervention methodology and the gradual implementation of stabilisation treatments for the paintings of the Main Church, informed by scientific analysis of the principal agents of deterioration. A combined conservation-science approach is recognised as the best means to maintain the long-term preservation of the Gelati Monastery and its invaluable artistic and architectural heritage.

A critically important intervention completed in September 2024 is the protection of the whole main church beneath a secondary temporary cover, with plans for this to be soon extended to the dome. This provides essential interim protection for the church while the conservation programme is ongoing.

Original Technology[20]

The wall paintings in the main space of the Church of the Nativity of the Virgin Mary span multiple periods, including early painting (probably 12th century), and the principal phases dating from the 16th and 17th centuries, and the 18th-century phase of selective repainting[21].

Building material

The church buildings are constructed from dolomite stone, which is mainly composed of the mineral dolomite [MgCa(CO3)2][22]. The masonry consists of stone blocks of various size, mostly rectangular in shape. Triangular stones are used in the pendentives, the shape of the stones in the vault of the arms of the church is curved, on the surrounding

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[20] https://gelatirehabilitation.ge/uploads/documents/docs/Research-Summery_2024.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/Gelati_wall-painting_report_GEO_FEB2024.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/English_Summary.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/Gelati_wall-painting_report-summary_ENG_FEB2024.pdf

[21] Wall Painting schemes at the main space of the Church of the Virgin Mary

[22] GELATI MONASTERY (GEORGIA) CHURCH OF THE NATIVITY OF THE HOLY VIRGIN (1106 AD) SCIENTIFIC INVESTIGATION ON THE MURAL PAINTINGS; Report by Dr. Geol. Davide Melica; Dr. Federica Antonelli, Consulenza e Diagnostica per il Restauro e la Conservazione; July 19th, 2021;
Church of the Virgin (Gelati) Salt analyses – Part II; Report by Prof. Dr. Steffen Laue, University of Applied Sciences Potsdam, Department of Conservation and Restoration, Science Laboratory; July, 2024

walls semi-curved, and at the edges of the pendentives, they are semi-columnar or rounded, in accordance with the architectural elements.

Despite the general regularity of the stone blocks, there is considerable variety in their quality and cutting. The topography of the walls is therefore uneven, which determines the topography of the paintings. On the surface of the stone blocks, traces of cutting and tooling remain, seen as thin, multiple incisions. Mortar between the stones can be seen only in a few places. As the blocks were usually very closely positioned next to each other, the gap/joint between them is either not visible or very thin (up to 5-10 mm). The mortar in between the stone joints is lime-based with inorganic inclusions. It is worth noting that this is similar to the lowest (and therefore earliest) painted plaster revealed in the western arm, which can be convincingly dated to the 12th century (see below).

Earliest Wall Paintings (12th century ?)

Recent activities and investigations have enabled the earliest layer of painting in the main space to be recognised, which is distinct both stylistically and programmatically from the church's main paintings. The techniques used in this early phase also differ significantly from subsequent phases.

Distribution

Fragments of the earliest painting layer are found on the vault of the western arm (depicting the Ascension of the Cross), the south wall (The Last Supper), and the north wall (Christ with Caiaphas). While the remains on the vault and south wall are monochrome, a figurative scheme is present under the Christ with Caiaphas scene. As a partial survival, this will require further interdisciplinary research (art history and technology) for a more comprehensive understanding.

The stratigraphy of this early layer consists of a light grey plaster, approximately 1 cm thick, with a fine inorganic aggregate filler. In some areas, a preparatory layer of uneven thickness (mostly around 0.2 cm) with an inorganic filler has been detected. The surface has a smoothed , even texture, and its material composition is similar to the main plaster layer, making it difficult to visually distinguish the two layers in certain places.

Unfortunately, the painting was compromised by reintegration carried out during the 2021-22 treatment phase. As the extent of reintegration was not documented at the time, this now complicates efforts to distinguish the original from the reconstructed layers. Only a small portion of the original paint layer has survived. The visible color palette is limited, consisting of distinct shades of blue, green, red, and yellow. Analytical investigations have confirmed the use of natural ultramarine as a blue pigment. The composition of the plaster and the style of brush strokes, along with the color palette, closely resemble the 12th-century paintings of the narthex, and on this basis the same date can be reasonably ascribed to the newly discovered fragments painting in the Main Church.

16th-Century Wall Paintings

The main space contains paintings executed in multiple stages: the early 1520s, 1550s and 1560s-1570s. The predominant scheme belongs to the 1550s period.

1520s Wall Paintings

The 1520s paintings are primarily located in the eastern apse, and were partially revealed during 20th-century restoration endeavours. The plaster in this area is a grey mix with a white binder, containing polymictic inorganic fillers and various organic inclusions such as straw-like inclusions, with plant ear parts.

The color palette has ochre tones ranging from light yellow to dark red, abundant greens, and modelling in white and black. Yellow, red, and green pigments appear to be earthen in origin. The paintings have survived in relatively good condition and remain close to their original appearance. The surface of these paintings was keyed, which was presumably done to anchor the subsequent painting phase.

1550s Wall Paintings

The paintings from 1550s are found in the eastern apse and bema of the main space (which was partially repainted in the 18th century); registers II, III, IV (vaults)[23] of the southern and western arms; and register IV (vault) of the western arm of the main space.

The number and composition of the plasters present, as well as the plastering and preparatory techniques vary depending on the distribution of the paintings in the main arms of the church:

Northern arm of the main space, registers II, III, IV. The **plaster** is mainly single-layered. It is greyish in color, with a lime (calcite) binder and a large aggregate component of river sand of various colors and a small amount of dolomite admixture, as well as transparent fibers of organic white color and in places, yellowish straw-like inclusions. The proportion of binder to filler is 1:1. There are few variations from the single-layer plastering approach. Only in one place is found an additional patch of painted plaster, sharing the same compositional features as the main plasterwork, which was probably applied to acommodate a change in the painted composition. In one other location, under the main plaster there is another plaster layer containing only organic inclusions (yellow straw).

[23] Registers are numbered from the floor level upward; therefore, the IV register corresponds to the vault level of the arms

The plaster joins follow not only the scaffolding levels and the dimensions of the main scenes, but also the internal scenes divisions and their compositional features. For example, the Pentecost scene is divided into 4 parts, in which the individual figures of the apostles and other compositional elements are accorded separate plaster patches. An exception to this approach is found on the vault, which is plastered as a single expanse. Similarly, the Annunciation on the western wall of the VI register is only divided into two patches.

Eastern arm of the main space – The plaster composition of the scenes on the bema and under the conch in the eastern arm of the main space matches the composition of the northern arm plaster. (The similarity was revealed as a result of microscopic observation, but requires additional analytical studies at a later stage).

In the east arm the plaster joins generally follow the scaffolding levels and the scene borders, although in large horizontal scenes are subdivided by vertical plaster joints.

Southern arm of the main space, registers II, III, IV[24]. The **plaster** here is applied in two-layers. The lower plaster is a mixture of dolomitic lime binder with a small amount of calcite and organic admixture (straw). This plaster is applied roughly to the surface of the wall, creating an uneven topography. The upper plaster has a greyish appearance and is a mixture of calcitic lime binder and river sand aggregate, which has a small amount of dolomite and organic white transparent fibers. The proportion of binder to filler in 3:1.

The plaster joins of the upper three registers of the southern arm are more segmented than the plastering of the other arms. The plaster joins, in addition to following the scaffolding levels and the frames of the scenes, delineate mutiple internal compositional parts of the scene. For example, the scene of Christ Emanuel in the vault is plastered in 5 parts: first, the figure of Emanuel was plastered in the center of the scene, then around him, in 4 patches, the symbols of the evangelists were plastered and painted.

Western arm of the main space, IV register - vault. The **plaster is** applied in two-layers. The lower plaster layer, which is lime-based, contains a large number of varied inorganic aggregates and organic, yellow-colored organic straw inclusions. The upper plaster layer is similar to the lower layer, although white-colored transparent organic fibers were additionally detected here. Analysis confirms that the upper plaster is a mixture of calcite binder and river sand aggregate in a ratio of 2:1. Identified organic inclusions include straw as well as hemp fibers. Another type of fibrous inclusion was identified as sheep wool in a 2022 study, although the current wall painting conservation team is conducting additional studies to verify through analysis whether this is of animal origin (sheep wool) or flax fiber.

[24] See footnote 23

As elsewhere, **the plastering of the IV register** of the western arm generally follows the scaffolding levels, and the scene dimensions and registers, as seen, for example, in the scenes on the northern wall, Christ with Caiaphas and the Judas Kiss. In the latter scene, in the western corner, there is also an anomlaous single patch which is somwhat raised above the level of the adjacent plasterwork and characterised by its differentiated painting. This is probably a correction or adjustment made at a late stage in the painting process. The plastering of the scene, Praying in Gethsemane, on the western wall differs again, the composition divided according to several plaster patches in thematic groups. The scenes on the southern wall of the western arm (Last Supper, Washing of the Feet) are plastered with a partial compositional division, according to the frames of the scenes and taking into account the level of the scaffolding.

In all three arms, **preparatory techniques** for painting comprise two main types, **geometric setting out** and **preliminary drawing**.

Setting out: the techniques used for setting out major compositional features such as architectural elements, scene divisions and frames, and other geometric components (eg, halos) include snapped lines (either dipped in paint so that a colour imprint is left on the wall by the snapped cord; or without paint, whereby the snapped impression is left in fresh plaster); incised horizonatla and vertical lines, in both fresh and set plaster; and circles drawn or incised by compass.

Preliminary drawing: is executed both with rapid, freehand paint strokes and with incisions in the plaster. These techniques are used to delineate features such as facial details, the shapes and locations of hair, drapery outlines and folds, and various decorative elements.

In the south arm, it is noteworthy that in addition to the distinct composition of the plaster and the manner in which the plasterwork is divided into zones and patches, the approach to utilising preparatory techniques is also significantly different from the schemes of the upper three registers of the north arm and the fourth register of the west arm. In the south arm, the preliminary drawing incisions are more detailed, and the setting out technique for the composition division – a snapped line dipped in pain – is exceptionally applied to the lower plaster layer (for example, the Annunciation scene on the west wall of the arm).

The **paint materials and application techniques** of this period are both stylistically and technologically diverse.

Earth (yellow, red, green) and lead-containing (white, red, yellow) pigments are found in all locations, providing a techncial 'marker' of this painting phase.

The painting in registers III and IV of the south arm differs from other locations in the use of a mercury sulfide pigment (cinnabar/vermilion), which has so far been found in the

Nativity scene (south wall of the south aisle, S6) and in the east window wall (east opening of the south arm, next to the scene of St. George, S10);

A pigment containing lead and tin (yellow in color) was primarily used to highlight bright accents in compositional elements, such as the tips of angels' wings and clothing contours. At this stage, it has been identified in the Annunciation scene (southern arm, east wall, E6) and the Lamentation scene (southern arm, east wall, E15)

Blue pigments are found in distinctive locations, indicating that discriminating choices were made, perhaps as a result of different teams of painters working side by side. For example, in Register IV on the vault of the western arm, smalt is the only blue pigment used here. On the other hand, in Registers III and IV in the Northern arm smalt is found alongside both azurite and artificial ultramarine, but the latter blue pigment is only found in these locations[25]. Azurite is also found in Register II in the northern, eastern and southern arms.

In addition to these pigments, gold is used in the southern and eastern arms for halos, mandorlas and on draperies.

Therefore, as a result of the diagnostic and analytical studies completed at this stage, the paintings of the 1550s can be divided into three groups based on similarities and differences in their technical and stylistic characteristics: 1: compositions in the upper three registers of the south arm, 2: compositions in the west arm vault level (fourth register) and 3. compositions in the upper three registers of the north arm.

The repaiting of the east arm in the eighteenth century complicates interrogation of the 1550s painting in this part of the church. Some similarlities can be discerned, for example between the apse and northen arm plaster composition and plaster patching, the gold is used both in apse and in south arm. Therefore further research is required to resolve eastern arm and other technical questions. [26]

<u>Paintings of the 1560s–1570s:</u>

Distribution – North and South Arms of the main space, Register I; West Arm, Registers II and III:

Plaster: The plaster found in Registers II and III of the western arm is completely different from that of of the early painting scheme (12th century), as well as from the 1520s and

[25] On the basis of research carried out in 2021-22, the ultramarine on register IV of the northern arm was identified as an artificial pigment; It should be noted that the production of artificial lapis lazuli begins in the 1820s, so the use of the mentioned pigment should be related to the late period.

[26] Diagnostic and analytic studies are continued to determine organic components, pigments and paint layer stratigraphy

1550s phases. It consists only of a white carbonate binder (ie, lime) and organic inclusions; inorganic aggregates are almost completely absent. The plastering is applied according to the height of the orginal scaffold lifts, and the scenes are additionally divided horizontally into two. The large size of these plaster divisions probably indicates a 'dry' painting technique throughout the painting process. This view is also supported by the condition of the paint layer, which exhibits extensive flaking due to poor adhesion, presumably provoked by the failure of an added binding medium.

The paint layer differs in stylistic modeling of the figues and partly in color palette, from the 1520s and 1550s paintings of the main space of the church.

In painting of this period (1560–1570), use of a mercury sulfide pigment (cinnabar/vermilion) is found in the first register of the northern arm, in the depictions of the kings, and in the western arm (the Virgin Mary's Washing the Feet, S13). Gold is found both in the deiction of kings in the northern arm and in the first register of the southern arm, while azurite, lead, and earth pigments are common in all three arms.

17th century wall painting (1657–1660)

This painting phase in the main space of the church is found only on the lower register of the western arm.

The plaster layer of this period is similar in composition to that of the 1560s–1570s phase, but differs in the plastering technique: the surface of the plaster is worked using a fine tool, which creates a wavy texture with small strokes. This type of plaster working is not recorded eslewhere. The plaster consists of carbonate binder (ie, lime) and organic inclusions. The plaster sections follows the levels of the original scafolding, and in some cases the scene divisions.

The paint layers are badly deteriorated andmostly lost, and consequently the original palette is not fully legible. For example, the background of the scenes is missing, and only small particles of blue pigment can be discerned by portable microscropy.

Earth- and Lead-based pigments are widely used in this painting phase. Technologically, Interestingly, the figure of Zakaria Kvariani, the donor, is technicaly distinguished by the abundant use of mercury sulfide pigment (cinnabar/vermilion). It is likely that organic paint materials were also used in this phase, but additional analytical studies are required to verfy this.

Note:

The diagnostic and analytical research of the wall paintings of the Church of the Nativity of the Virgin Mary, conducted between 2021 and 2024, provides a detailed understanding of the artistic and technological developments of the sequential painting phases of the church's history. However, the study is ongoing, with further investigations scheduled for

2025. This will continue to refine our understanding of the church's wall paintings and their historical and technological significance.

Previous conservation intervention materials

The latest analytical investigations into XX century repair materials have revealed composition of the repair material such as gypsum and lime-based materials (containing pozzolanic material and/or sand, with a binder-to-filler ratio of 1:3[27]. As a paint and plaster fixative following materials have been identified: wax and poly vinyl acetate[28].

Between 2021 and 2022, various materials were used for plaster stabilization and conservation. Acrylic adhesives, including Polval acrylic emulsion, Paraloid B72, ACRIL 33 and ALCOOL POLIVINILICO and an unspecified methylacrylate-ethylmethacrylate resins, were applied. For plaster consolidation, ethyl silicate, ammonium diphosphate, and ammonium oxalate (including AMMONIO OSSALATO and AMMONIO FOSFATO BIBASICO) were tested. Detached plasters were grouted using PLM-A and PLM-AL. Additionally, salt extraction and biocide application were carried out[29].

Condition of the paintings

Introduction

Since April 2023, detailed condition monitoring and assessment have been undertaken at the Church of the Virgin Mary. Very severe conditions are present in the upper registers of the east, west, north and south arms. Historical and relatively new deterioration has occurred, relating not only to architectural failures inherent in the centuries-old building, but also to rainwater infiltration during the roof rehabilitation in 2015-2018, which has persisted in various places up to spring 2024. The combined impacts of unstable climatic conditions, the susceptibility of original painting technologies to these conditions, and the repeated failure of previous restoration/conservation interventions (up to including those made in 2021-22) have in many areas critically undermined the integrity of the paintings.

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[27] GELATI MONASTERY (GEORGIA) CHURCH OF THE NATIVITY OF THE HOLY VIRGIN (1106 AD) SCIENTIFIC INVESTIGATION ON THE MURAL PAINTINGS - PART II; Report by Dr. Geol. Davide Melica, Collaborators: Dr. Manuel Jardón Cabezas, Dr. Llucia Bosch Rubio; Consulenza e Diagnostica per il Restauro e la Conservazione; November 23rd, 2022

[28] Investigations undertaken by Professor Steffen Laue, University of Potsdam

[29] See physical history for references.

Critical areas/conditions

Damage and deterioration of the wall paintings are almost comprehensive in their extent, though degrees of severity and risk vary. Although defining risk is not straightforward, since conditions of failure are not fully predictable, certain 'critical areas/conditions' have been identified and documented, and they are prioritised within the overall conservation plan. It is important to acknowledge that although concerning loss of original plaster is ongoing, a remedial approach is normally only considered feasible and safe to implement *after* activation mechanisms are brought under control. Remedial treatments carried out prematurely risk being short-lived while deterioration agents remain active.

Especially challenging are large zone of painting in the upper registers, principally including the two scenes on the south wall of the western arm (the Last Supper and Washing of the Feet); the niche in the western arm; the north-west and south-west pendentives; the arches between the pendentives; numerous scenes in the North and South arms (especially, The Raising of Lazarus, Presentation of Jesus, Pentecost, Transfiguration of Jesus). The combined and multiple problems in these areas include severe salt efflorescence, plaster delamination and disintegration, and powdering, flaking and loss of paint layers.

Condition phenomena

In general, the following forms of deterioration and damage have been identified and documented:

• For the primary support – loss of mortar, stone decohesion, stone cracks;

• For the plaster layer – loss, decohesion, delamination, pitting and cracks;

• For the paint layer – loss, cohesion and adhesion failures, mobilised paintwork;

• Biological activity and colonisation (including most obviously, pink and black microorganisms);

• Surface depositions (accumulated dust and dirt, etc.);

• Pigment alterations and other forms of inherent failure

• Salts

While the occurrence and distribution of these varied phenomena vary considerably on the interior of the church, they are typically found in complex combinations over wide areas[30].

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[30] Graphic Documentation_Church of the Virgin_Main space_East arm_2023
Graphic Documentation_Church of the Virgin_Main space_North arm_2023

Specific causes and activation mechansims of damage and deterioration

Salt-related deterioration

Salts are a major agent of deterioration, especially in the upper registers of painting and on the vaults. Their presence in these locations indicates the role of historic (and more recent) water infiltration in transporting soluble salts to the plaster and paint layers from sources within the fabric. Damaging cycles of salt crystallisation and deliquescence continue to be driven by unstable climate conditions, causing ongoing weakening of the plaster and paint materials.

Technology and environment-related deterioration

Failure associated with salts is only the most obvious form of deterioration. Since several phases of painting are present, technological differences between them – and aspects of inherent failure that may be particular to each phase – are also major and widespread deterioration considerations, which are also largely driven by environmental factors. Several examples can be highlighted, as follows:

- West arm, Register III, especially south wall: localised flaking of paintwork from faces and hands, probably associated with specific aspects of painting technologies employed here, and with environmental conditions;

- Small losses and pitting associated with organic (and other inorganic?) inclusions, found to varying extends in all the painting phases;

- Differential behaviours of the varying plaster types – such as the extent and nature of cracking, and degrees of adherence and conformity – which are partly related to aspects of their original application procedures and setting processes (eg, rate and hardness of set), and partly to their responses to current thermohygral conditions (and gravity);

- The influence of the primary support on setting and shrinkage of the applied plasters, especially in relation to the joints between the stone blocks, and the transference of cracking to the superimposed plasters;

- The inherent susceptibility of specific pigments and other paint materials to environmental degradation (eg, smalt, lead-based pigments, etc.).

Graphic Documentation_Church of the Virgin_Main space_South arm_2023
Graphic Documentation_Church of the Virgin_Main space_West arm_2023

Biogenetic deterioration

The role of biogenic colonisation and deterioration is understudied but widespread, manifesting in numerous ways. From preliminary investigations already carried out, colonisation patterns include technique-specific behaviours. For example, a pink dot colonisation can be associated with the 16^{th} and 17^{th} century lime-based plasters, and linked to corresponding losses of the plaster and paint layers

Human-related damage

This includes both **vandalism** (scratching, inscriptions, etc.) and **mechanical damage** resulting from use of the space (including the previous construction and use of scaffolding). But the predominant and most concerning from of human impact is from **previous interventions**, which include retouchings/repainting, consolidation/fixing of plaster and paint materials, and repairs with inappropriate materials (mainly gypsum). In combination with the unstable climate conditions and periods of water infiltration, these interventions have contributed more to deterioration processes than if they had not been implemented.

Salts [31]

The information collected and analysis carried out so far show that, in addition to some gypsum (calcium sulfate), at least three other predominant salt systems contribute to onging salt damage in the Church of the Virgin. They are magnesium carbonate, magnesium sulfate and potassium nitrate.

In addition, in some samples, double salts with two cations and sulfate have also been detected (aphtitalite, picromerite and syngenite). This iindicates not only the complexity of the salt mixtures present in at least some areas of the walls, but also the difficulties in defining their phase change parameters precisely.

Although the salt ion contamination in the church is heterogeneously distributed and different salt ion mixtures occur in different quantities, the following damage scenarios can be suggested based on the qualitative and quantitative salt analyses so far completed.

The church is constructed from blocks of dolomite stone, which consists mainly of the mineral dolomite [MgCa(CO3)2]. Dolomite is also present in at least two plastering

[31] Steffen Laue, Church of the Virgin (Gelati) Salt analyses – Part I
Steffen Laue, Church of the Virgin (Gelati) Salt analyses – Part II, University of Applied Sciences Potsdam, Department of Conservation and Restoration, Science Laboratory

phases. The use of dolomite-lime mortar cannot be ruled out either. Dolomite is a poorly soluble mineral, but due to moisture ingress over a long period of time, dolomite components can be dissolved and soluble ions transported. On drying, magnesium carbonate and magnesium carbonate hydrate phases crystallize to form the mineral salts magnesite [MgCO3], hydromagnesite [Mg5(CO3)4(OH)2•4H2O], nesquehonite [MgCO3•3H2O], lansfordite [MgCO3•5H2O] and dypingite [Mg5(CO3)4(OH)2•5H2O]. These have all been identified currently on and in the plaster and paint layers.

If, in addition to these magnesium carbonate minerals, a sulphate source is added – for example from gypsum repairs made in the 1980s, or from pollutant gases, which in previous years probably existed for long periods in the city of Kutaisi and were transported by winds – magnesium sulphates such as epsomite [MgSO4•7H2O] and hexahydrite [MgSO4•6H2O] are formed after moisture ingress and drying, both of which have been detected in samples taken from the paintings. Magnesium sulfates are more soluble than magnesium carbonates and have the additional damaging property of hydrating and dehydrating depending on relative humidity variations.

At higher relative humidities, epsomite is the stable phase, while at lower humidities hexahydrite is most likely present. This means that the two salts convert into each other depending on the climate. The crystal lattice collapses briefly and then the new phase crystallizes with corresponding volume changes and damage to the porous system. Although we do not know the exact climatic conditions under which the transformation takes place (it depends, among other things, on temperature, relative humidity, ion composition of the ion mixture prevailing on the surface), it is in any case advisable to reduce magnesium sulfate ions from the surface area in order to avoid the hydration and dehydration processes of this special salt system.

Sulfate ions present on surfaces frequently react with calcium ions, which are always found in buildings, to form the poorly soluble mineral gypsum [CaSO4•2H2O]. Gypsum only dissolves when there is a film of moisture on a surface, which is the case in the church due to water ingress and possibly also due to condensation events[32].

In addition, the quantitative salt analyses of all measured surfaces show a high alkali content of sodium and potassium as well as a high pH value in the plasters. Reasons for this have not yet been clarified.

In addition to the salts with two cations, syngenite [K2Ca(SO4)2•H2O], aphtitalite [K3Na(SO4)2] and picromerite [K2Mg(SO4)2•6H2O], niter [KNO3] is often found, above all as an efflorescence salt. Niter has the special property that its solubility is strongly temperature-dependent: at high temperatures, niter is highly soluble, but at cold temperatures the solubility is greatly reduced, which leads to crystallization preferably at cold temperatures. Consequently, increased damage processes have been observed in

[32] Has not been detected so far

winter months in several monuments (Laue 2006, Laue 2023), and this is likely to be occurring at Gelati, too

High sodium content and an excess of cations in the upper 1 cm increment of the walls are noticeable in respect to the analyzed ions. The excess of cations can be explained by the anions oxalate and carbonate, which are not included in the ion balance.

Oxalate has been detected but not yet quantified, and carbonates cannot be measured using IC.

Although high amounts of sodium have been detected on the painting surface, hardly any crystallized sodium salts have been found so far. However, these salt ions have the potential to become damagingly active when climatic conditions change. Since all sodium salts are high soluble, salt reduction measures could help to improve the situation.

Note:

The reason for the high alkali content on the surfaces of the paintings needs to be determined. Possible causes could be related to historic treatments in 18-19th centuries, when alkaline conservation materials may have been used.

Environmental monitoring and correlation with wall painting condition and salts[33]

Absolute humidity

In 2024, trends in the absolute humidity index for the exterior and interior of the main church show a consistent pattern across all four interior arms, indicating that the macroclimate (especially rainfall) is the primary influencing factor on the climate of the main space. The absolute humidity index inside the church ranges from 2.4 to 21.9 g/m^3, with seasonal variations as follows:

- Winter: 2.4 to 8.12 g/m^3
- Spring: 3.2 to 17 g/m^3

[33] Gelati, Church of Virgin, Main space, Envrionmental Monitoring report 2024
Gelati, Church of Virgin, Envrionmental Monitoring report 2023
Gelati, Church of Virgin, Envrionmental Monitoring report 2020-2022
Gelati, Church of Virgin, Envrionmental Monitoring report 2021_September
Gelati Environmental monitoring strategy

- Summer: 9.29 to 21.9 g/m^3
- Autumn: 4.2 to 18.87 g/m^3

The absolute humidity index increases gradually with the changing seasons, reaching its highest levels during the summer months. This seasonal rise in absolute humidity correlates with an increase in relative humidity.

While the absolute humidity trends and indicators for the interior and exterior are generally aligned, some differences emerge in spring and particularly in summer. During these seasons, the exterior absolute humidity shows lower moisture content and instability, whereas the interior humidity levels are consistently higher and slightly more stable.

This discrepancy may suggest the possibility of an additional source of interior moisture beyond macroclimatic factors (such as contributions from water ingress, condensation, rising damp/underground water). It also should be mentioned that the introduction of wooden materials, such as scaffolding, during the restoration and construction works could contribute to the elevated and stabilised interior moisture levels.

Condensation and infiltration

Condensation has not been detected on the wall paintings surfaces since 2020[34]. To verify previous findings, new surface temperature sensors were installed in the arms of the main space on different levels in October 2024. Data analysis from these does not show any condensation events in the autumn and winter seasons.

Significant water infiltration occurred twice in 2024, from February 5th- 6th and on March 26th, affecting interior humidity levels (on these days rainfall data also showed high peaks)[35].

Relative humidity levels

According to the 2024 data, the relative humidity in the main space of the Nativity of the Virgin Mary Cathedral exhibits significant instability across annual, seasonal, and daily measurements. The hygral buffering capacity of the main space is weak, meaning it is unable to regulate humidity effectively and is highly influenced by the macroclimate. All

[34] In 2023-2024 Infrared thermography and hygrometric measures were undertaken.
[35] As a result of processing data for 2020 – 2021; 2021-2022; 2022-2023; 2023-2024, condensation risks were determined by calculating the air temperature (before surface temperature sensor installation) and dew point: Over the 4 years from 2021 to 2023, the average risk of condensation was observed only during the spring and summer seasons, only for a few days; In the spring-summer period of 2024, the risk of condensation was quite low. See the graphs of environmental conditions.

trends and values within the arms are very closely aligned, however there are significant stratigraphic differences over the height of the interior[36].

Relative humidity within the main space ranges from 20% to 90%, with variations observed between the lower level (6 meters) and the upper level (18 meters)[37]:

- Summer: High relative humidity (≥70%) is consistently maintained on the lower level of the main space, persisting for approximately 90% of the season. At the upper levels, high relative humidity is observed for around 67% of the season in the north, east, and south arms, while the west arm experiences slightly higher levels, with high humidity present about 75% of the season. RH values in the upper levels do not exceed 88% humidity, except in August when the west arm recorded 94%. In contrast, maximum RH values in the lower levels exceed 95%. The lowest RH value of the season was 36%.
- Spring: High relative humidity (≥70%) primarily affects the lower level, persisting for approximately 50% of the season. The upper levels show a trend similar to winter, with high humidity lasting only 25–30% of the season, and no prolonged periods of elevated humidity. RH values in the upper level do not exceed 89% humidity, while maximum RH values in the lower level are higher. The lowest RH value of the season was 28%.
- Autumn: This is the driest season. High relative humidity (≥70%) at both levels remains minimal, not exceeding 12% of the season, and follows similar patterns and trends across the space. RH values in the upper level do not exceed 79% humidity, while maximum RH values in the lower level are higher, especially in September. The lowest RH value of the season was 19.6%.
- Winter: High relative humidity (≥70%) is relatively low, occurring in no more than 30% of the season. RH values in the upper level do not exceed 90% humidity, while the maximum RH value in the lower level reached 95%. The lowest RH value of the season was 27%.

Monthly and daily fluctuations in relative humidity are pronounced, with great differences between minimum and maximum values. Monthly difference can reach up to 60 units, while daily fluctuations reach maximum 45 units.

These findings highlight the inability of the main space to buffer changes in humidity, leaving it vulnerable to macroclimatic conditions and significant daily and seasonal variations.

Temperature levels

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[36] The difference between levels could also be connected to the accuracy of the sensors (above 80%; RH accuracy is at least +/- 6 according to the data sheets).

[37] In each arm of the main space two sensors are installed on 6meter level and 18.5 m level.

The interior of the main space demonstrates a relatively effective thermal regulation function, with interior temperature trends only slightly influenced by fluctuations in exterior temperatures. A sharp increase in exterior temperature results in a maximum interior temperature rise of 4 °C, while a sharp decrease in exterior temperature has a lesser impact on the interior.

In 2024, exterior temperatures fluctuated between -3.95 °C and 39 °C, while the annual temperature variation inside the arms of the main space ranged from 6 °C to 29 °C. These data indicate that the building exhibits weaker resistance to temperature increases but remains more stable and resistant to temperature drops.

In Winter temperatures range from 6°C to 16°C, in Spring from 8°C to 25°C, in Summer from 18°C to 29°C and in Autumn from 9°C to 29°C. The temperature differences at sequential heights on the interior usually only vary within 1°C; however, in summer 4°C difference has been observed. At the uppermost level (18.8m), temperatures are always higher than those at lower levels.

Airflow in the Main Space

In the main space, the airflow from the exterior occurs primarily through the following pathways:

- West: Through the narthex door.
- North: Through the north door.
- South: Through the south door.

Additionally, there is a system of shutters on the window openings, which facilitate air exchange. During the spring, the lower part of the opening was unsealed to support the scaffolding structure. Despite this, the openings in the western, northern, and southern window frames continued to serve as sources of air circulation.

Impact on Wall Paintings

The collected and evaluated environmental data indicate the fundamental influence of unstable climate conditions in driving nearly all deterioration processes[38], chief among them salt-related deterioration. Biodeterioation, as yet not fully studied, is likely to be another dominant deteriogen intimately linked to climate fluctuations.

Salts provide a useful visual ‘marker’ to track the adverse impacts of the climate. A programme of careful monitoring is ongoing to correlate wall painting conditions – plaster disintegration and powdering, paint flaking and loss, etc. – with climate parameters. Monitoring areas have been selected from zones of known salt activity, and based on analytical finds also represent the 4 main salt groups that have so far been identified in

[38] Losses particularly in the Autumn and Winter seasons

the walls (ie, gypsum, magnesium carbonate, magnesium sulfate, and potassium nitrates).

In 2024, macroscopic monthly monitoring was undertaken in these areas to elucidate salt dissolution-crystallization processes. So far, monitoring from Autumn 2023 to December 2024 has detected new efflorescence of potassium nitrate and magnesium sulfate in the main space[39], while magnesium carbonate and gypsum have remained macroscopically unchanged.

As already discussed, potassium nitrate and magnesium sulfates are known to deliquesce at high relative humidity levels (above 90%), while phase changes in potassium nitrate are also temperature-dependent. In 2024, RH values above 90% were not recorded in the upper levels of the arms, which may explain the absence of detectable deliquescence phases for these salts. However, the presence of salt mixtures such as syngenite **[$K_2Ca(SO_4)_2 \bullet H_2O$]**, aphthitalite **[$K_3Na(SO_4)_2$]**, and picromerite **[$K_2Mg(SO_4)_2 \bullet 6H_2O$]** suggests that lower RH levels could still be sufficient for their deliquescence. Therefore, continued monitoring and further research are necessary, along with the refinement of techniques such as 3D monitoring, for which preliminary trials were conducted in October 2024.

Remedial interventions[40]

Context

Multiple types of deterioration have undermined the condition of the Gelati paintings over a long time-period, probably on an almost continual basis since the building of the monastery church. The size and complexity of the structure present an intrinsic risk of rainwater infiltration, and there is evidence that this has occurred repeatedly. The widespread presence, deliquescence and crystallization of complex salt mixtures are among the most prevalent and serious problems. Extensive and diverse forms of

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[39] In the west arm Niter was efflorescence during the Winter season (Minimal RH value detected as 28% in the upper level of the west arm) and remained almost unchanged including December 2023; In the North arm Niter efflorescence happened during the summer period (during this period, in June and July the lowest RH was 47% in an upper level.

[40] https://gelatirehabilitation.ge/uploads/documents/docs/Gelati_Wall-Painting-remedial-treatment_Phase1_March_2024.pdf
https://gelatirehabilitation.ge/uploads/documents/docs/Gelati_Wall-Painting-remedial-treatment_Phase2_August_2024.pdf
Graphic documentation of the remedial treatments_March_December 2024
Remedial treatments_August_Decemmber 2024

biological deterioration and their effects are also serious concerns. In consequence, large expanses of painting exist in altered and highly vulnerable states and many areas are at risk of loss.

Collected environmental data indicate highly variable and unstable conditions, with probably few options for mitigation. The conservation history demonstrates the persistent failure of most previous interventions.

In this context the wall painting conservation programme incorporates the following:

- It recognizes that irremovable and inexorable deterioration factors place considerable limitations on both the implementation and efficacy of remedial interventions;
- It limits remedial treatments to essential stabilization measures, carried out within a framework that privileges compatibility and minimal intervention; and
- It integrates the planning and implementation of remedial treatments with diagnostic, analytical and environmental investigations and outcomes.

Treatment programme

In March 2024, the Gelati wall painting conservation team began a remedial treatment programme which is intended to provide a model of conservation planning and implementation, by:

• acknowledging diagnosis of deterioration, risk assessment, and variable aspects of condition and technology in treatment design and implementation;

• adhering to modern conservation standards and principles, in particular minimal intervention and compatibility;

• challenging a culture of use of poorly selected conservation materials through a program of testing and development that stresses assessment of performance criteria and working properties, compatibility, stability, etc.;

• observing implementation criteria that emphasize restraint and surveillance of results;

• demonstrating the importance of placing remedial treatment within a wider context of other conservation measures (salts and moisture investigations, environmental monitoring and control).

The wall painting treatment programme for the Gelati wall paintings has three parallel tracks:

• treatment of ‘critical areas’

• general stabilization treatments

• identification/development of specialist treatments (and related investigations)

General stabilization treatments

The following principal remedial treatments have been developed and trialled, and are being gradually but progressively implemented in the north arm, and on the pendentives and their connecting arches:

Plaster consolidation: use of nano-lime dispersed in alcohol. Colloidal dispersions of $Ca(OH)_2$ nanoparticles offer several advantages: compatibility with the original plaster materials; proven efficacy in limiting carbonation of the nano-lime particles by CO_2 before they have been deposited in the substrate; appropriate penetration depth, strength, hardness, surface cohesion, capillary absorption, etc.; and little or no change of internal pore structures, so that effective porosity is maintained in the original materials. Very importantly, as nano-limes are dispersed in alcohols, risks of mobilising salts are avoided. Treatment monitoring to date has indicates good outcomes.

'Micro-grouting': Some conditions of plaster disaggregation cannot be adequately treated with the nano-lime formulations, and a lime-based 'micro-grout' has been developed instead. This is intended to consolidate/bridge larger dissagregated particles in deteriorated plasters. Part dilution with alcohol minimises salt risks. Monitored results and outcomes have so far been positive.

Plaster re-adhesion (injection grouting): Cracking, fragmentation and separation of plaster are widespread and generally urgent problems. In many places large expanses of painting are at risk of collapse and loss. Plaster edging repairs made in the past to secure these areas are insufficient (and in many cases are also failing). This situation of uncertainty cannot remain unaddressed. Injection grouting is now the accepted treatment procedure for addressing issues of endangering plaster separation. Injection grouting reestablishes adhesion between the separated layers of a wall painting by introducing an adhesive material with bulking properties.

Based on considerable previous research and largescale implementation, a customised lime-based grout is being used. Its designed properties include compatibility, stability, no salts, fast-setting, expansive (and therefore non-shrinkable), light weight, bio-resistant, low water content and retreatability.

As some areas of plaster separation are salt contaminated, specific improvements and protocols are being developed to further limit salt activation risks.

Plaster repairs: plaster fills and edge repairs probably constitute the main remedial treatment historically carried out on the wall paintings. Several phases and types of intervention are distinguishable, representing shifts in approach over time (including use of gypsum repairs). In all cases, single-type repairs have been applied on an overall basis irrespective of variations in the condition and technology of the original plasters. Many repairs are too hard and dense in comparison with the weaker original plasters, resulting in preferential moisture/salts movement into the original materials, with detrimental effects. These repairs also tend to fail at their interface with the weaker original plasters, rather than internally, leading to separation and loss. The gypsum repairs are a source of added salts.

Plaster repairs have been also used to support large expanses of separating plaster, which would now be secured by injection grouting (see above). In consequence, an emphasis in their formulation was to maximize strength properties. This has been detrimental to the weaker original plasters.

For the Gelati wall paintings, repairs need to be: • compatible with the technologies of the original plasters in terms of their principal binder type and aggregate ratios; • individualised to varying aspects of both condition and technology; • have good performance characteristics (low shrinkage, appropriate strength properties, appropriate porosity, etc.) • be formulated and applied with minimal water content; and • be constituted from dependable and locally available source materials.

Using information on the diverse technologies of the original plasters, more than 20 repair types were prepared, and their physical characteristics evaluated (eg, wet/dry density, hardness, color, texture, drying time, adhesion, water release, shrinkage etc.). A selection of repair formulations is now being implemented, and outcomes of their use and application carefully monitored.

Paint re-adhesion: Flaking and loss of paint layers is widespread. The deterioration is related to several interrelated factors, including inherent aspects of failure in the paint materials, climate conditions, and the disruption of salts. Re-establishing adhesion in a prevalent context of salt contamination is problematic, as the film-forming materials that are normally employed risk forming barriers for the movement of salts inherent in the system.

Therefore, trials have been carried out using different concentrations of nano-lime dispersed in alcohols. Early indications are that these can provide an effective means of resecuring some areas of paint flaking (eg, some green, white, and light pink paints). However, their efficacy on blue and red paints is questionable, or in areas where thick paint layers are present, and there is a need for adhesive properties to also have a bulking component. Challenges therefore remain.

Salt reduction - Salts are major agent of deterioration. The gradual and methodical mechanical removal of flake- and crust- like salts (mainly potassium nitrates and magnesium sulfates) and efflorescences has been conducted since March 2024, along with ongoing surveillance of results. (see Environmental Monitoring and Condition chapters).

Treatment of ‘critical areas’

Areas in ‘critical’ condition have been – and continue to be – identified by the ongoing programme of condition recording and assessment. The ‘critical areas’ are most often destabilised by separation of plaster layers from the primary support, representing risks of (sudden) collapse and (generally largescale) loss. Injection grouting is being carried out on a case-by-case basis to address these areas. However, as they are many and cannot be treated all at once, a system of prioritization is being followed, based on an assessment of various risk factors, as follows:

- **nature of separation:** including considerations of the location, size and state of deformation of the plaster separation. For example, large areas of plaster separation on vaults may be judged at greater risk than those on wall surfaces, due to added effects of gravity and greater risks of sudden collapse;
- **presence of other destabilizing conditions:** the presence of conditions such as interconnected plaster cracking which might increase risks of collapse are taken into account in sequencing the order and priority of injection grouting in the overall conservation programme;
- **presence of inhibiting conditions:** conditions that might inhibit grouting or introduce additional risk factors – such as the presence of salts – may mean that grouting interventions are delayed until a wider set of precautions and measures are set in place.

To offset the risks involved in phasing injection grouting over time, temporary stabilization measures are instigated (eg, application of facings), again depending on specific conditions and the options available. In one extreme case, emergency detachment and transfer have also been undertaken.

Identification/development of specialist treatments (and related investigations)

As the remedial treatment programme progresses, areas for the development of new specialist interventions are being identified. These are:

Salt reduction procedures: with the analytical identification that salt contamination is largely limited to the upper plaster stratigraphies, there is the prospect that effective salt reduction measures could be implemented in the remedial treatment programme. Appropriate materials and procedures need to be identified and researched, and trialled and evaluated in conjunction with continuing salts analysis.

specific flake fixing requirements: as indicated above, use of nano-lime dispersed in alcohols have limited efficacy for certain conditions of flaking paint. Further research and testing of additional/supplementary materials are required.