Safeguarding and conservation of Gelati Monastery
World Heritage Property, Georgia

Church of the Virgin

Investigations on the structural hygrometric and micro-environmental state aimed at safeguarding the internal wall paintings

Mission Arch. Alessandro Massari of: 06 – 12 November 2021

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INTRODUCTION

The study aims to survey the hygrometric state of the Church structures, particularly on the vault on the western branch of the building. The objectives are the identification of possible correlations between the hygrometric status of the bearing structures and the degradation phenomena on the surfaces (in progress or in the past). In addition, carry an initial assessment of potential measures to improve the hygrometry and the microclimatic parameters on the structures.

This report has been edited in the light of the technical documentation provided by the Client, visual investigations and instrumental surveys performed during the first mission at the Gelati Monastery between the 6^{th} and the 11^{th} of November 2021. Moreover, the information kindly shared by professionals and researchers on site, have been important for the study and, ultimately, the expertise and competence on restoration aspects of the friend Marco Puglieri has been pivotal.

A – CURRENT STATE

Below is reported the condition of the surveyed areas during the mission, specifically, are discussed the elements that may affect directly or indirectly the hygrometry on structures. For a more detailed representation of the situation refer to Sheet 1, edited based on the plans provided by the Client, thus integrated with elements observed during the survey and identified as significant for the study.

A.1 – EXTERNAL PAVINGS AND SURFACES

The Gelati Monastery is located about 10 km north-east of Kutaisi, near the Tskhalsitela river, and on a wide plateau (at about 400 m AMSL), with a small slope from east to west, itself situated along a steep crest of a hill complex that runs adjacent riverbanks. The monastery, enclosed by a low wall, consists of several buildings constructed in different periods around the Church of Virgin. The arrangement of the buildings adapts admirably to the morphology of the terrain with a clear emphasis on the east-west axis (a highly symbolic orientation in the Christian world) which is featured by the succession, westerly, of three churches, namely Saint George, Nativity of the Virgin and Saint Nicholas, and by Academy building (*figure 1*).

Figure 1: Gelati Monastery, aerial view from east with, at foreground, the St. George Church, followed by Nativity of Virgin Church

Water drainage system (both on surface and underground) corresponds to the terrain morphology; the latter has a lean prevailing direction from south-east to north-west, which is towards the valley bottom at the base of the hill complex. Traces of ancient drainage channels and water supply networks that cross the area support this thesis.

The Church of Virgin stands, in an isolated position, in the middle of the aforementioned plateau, which, in turn, approximately corresponds to the current perimeter of the monastery.

Figure 2: site plan of the monastery, taken from UNESCO website

In the current state the building is the result of a series of transformations and extensions between the XII and the XIII century: the main body dates, indeed, XII century and consists of a construction with three naves (with one central nave and two aisles), a central dome and three apses on the eastern façade; later, in the same century, were added a narthex on the west, an annex with a portal on the south and a chapel on the east and one on the west. During the XIII century other two chapels and another portal were adjoined to the main body on the northern side.

The interior floor levels of the church are only slightly higher than those of the exterior paving with a mild increase of the drop from east to west, namely towards the entrance, which is a result of exterior slope. Along the perimeter there is a modest modern pavement (about 1 m wide) made of in situ conglomerate to detach the Church from the surrounding lawn.

The rocks that emerge from the terrain suggest the existence of a quite superficial rocky bank, which was used as firm support for the Church structures.

The four façades display featuring conditions slightly different from each other as described below.

A.1.1 – West façade

The western front is characterised by a protruding low narthex which precedes the liturgical hall (figure 3).

Figure 3: Church of the Virgin Mary, view of the west and south fronts

At the base of the building there is a stone stepped plinth, consisting of three risers and four treads, the first of which is at ground level. Beyond the plinth, there is a low modern conglomerate sidewalk (approx. 1.1 m wide), interrupted at the entrance by a narrow path, paved with irregular stones (larger near the entrance).

On the far side to the pavement there are surfaces with various finishes (lawn or gravel) and slopes to direct water away from the building towards the west.

Along the front there are three downspouts (**d1**, **d2**, **d3**, in **Sheet 1**), plus a fourth (**d17**) at the north-west corner of the building, for the disposal of water coming from the current roofs (mostly temporary). The downpipes **d1**, **d2** and **d3**, are free draining on the ground, while **d17** seems to be connected to a sewage system with an unknown outlet (presumably towards the west elevation drop); all are provisional and made of sheet metal (*figures 4 and 5*).

*Figure 4: view of downpipes **d17** and **d1** in operation during the thunderstorm*

*Figure 5: view of downpipes **d2** and **d3** in operation during the thunderstorm*

A.1.2 – North façade

The northern front displays the two portals and chapels annexed to the main body of the church in the XIII century (*figure 6*).

The overall slope of the external ground runs from east to west.

At the base of the building there is a stone stepped plinth, consisting of two risers and two treads. Behind the plinth is, as mentioned above, the modern conglomerate pavement (approx. 1.0 m wide) detaching the construction from the surrounding grassland.

Along the front there are three provisional drainpipes (**d14**, **d15**, **d16**), made of 100 mm diameter sheet metal, for the disposal of rainwater from the actual temporary roofing. The three downspouts discharge water into 3 manholes (**sm-8**, **sm-9** and **sm-10**) with 50 x 50 cm grates, located immediately beyond the modern sidewalk. These manholes, below the grids, are made of vertically placed double cored PEAD pipes sections (300 mm diameter), whereas corrugated drainpipes (approx. 100 mm diameter) connected to them have an unknown destination.

Finally, as mentioned above, the drainpipe **d17**, at the corner with the west façade, appears to be connected to the drainage system without a connecting pit (*figures 7 and 8*).

Figure 6: Church of the Virgin Mary, view of the north front

*Figure 7: view of downpipes **d17**, **d16**, **d15** and **d14***

*Figure 8: detail view of downpipe **d15** with manhole **sm-9***

A.1.3 – East façade

The oriental front is marked by the imposing presence of the three apses, corresponding to the ends of the central nave and aisles of the main body, and the two side chapels (figure 9). At the three central apses, the stone plinth at the base of the building widens to form a kind of continuous platform discreetly raised from the ground. Along this front too, is the low modern conglomerate pavement which, however, is in places covered with earth and vegetation. The overall slope runs, as aforementioned, from east to west, therefore, tends to convey surface water against the building. There are six (**d7**, **d8**, **d9**, **d10**, **d11** and **d12**) provisional drainpipes made of 100 mm diameter sheet metal carrying water from the roofs of the central body of the church. Two more downspouts (**d6** and **d13**) channel water from the outer chapels' coverings. The downspouts, which have reached the ground, discharge into five manholes (**sm-3**, **sm-4**, **sm-5**, **sm-6** and **sm-7**), which have no gratings and are presumably connected to drainage networks with uncertain routes (*Figures 10 and 11*).

Figure 9: Church of the Virgin Mary, view of the east and north fronts

*Figure 10: detail view of downpipes **d8** and **d9** with the manhole **sm-4***

*Figure 11: detail view of downpipes **d10** and **d11** with the manhole **sm-5***

A.1.4 – South façade

The front features a large portal and two chapels added to the main body of the church in the XII century (*figures 3 and 12*).

*Figure 12: Church of the Virgin Mary, view of the south front with downpipes **d4** and **d5***

The overall slope of the land runs from east to west. At the base of the building there is a stone stepped plinth composed of two risers and two treads. Next to the plinth, exteriorly, is the modern conglomerate pavement (approx. 1.0 m wide) which, however, tends to disappear below the ground. Along this southern front of the building, there are two temporary downspouts (**d4** and **d5**, 100 mm diameter) which discharge into two circular manholes (**sm-1** and **sm-2**, 300 mm diameter) without gratings, located immediately beyond the low pavement (*figures 13 and 14*). Further away from the building there is another manhole with metal grating (600 x 400 mm) which indicates the presence of a drainage channel coming from the east (the alleged drainage pipe should be the same as the one visible along the north side of the Saint George Church indeed).

At the south-west corner of the church there is a sort of foundation (perhaps a preparation for an unbuilt extension) consisting of low stone perimeter walls and an earth filling in direct contact with the footing of the church (*figure 15*).

*Figure 13: detail view of downpipe **d5** with the manhole **sm-5***

*Figure 14: view of downpipe **d4** with the manhole **sm-1***

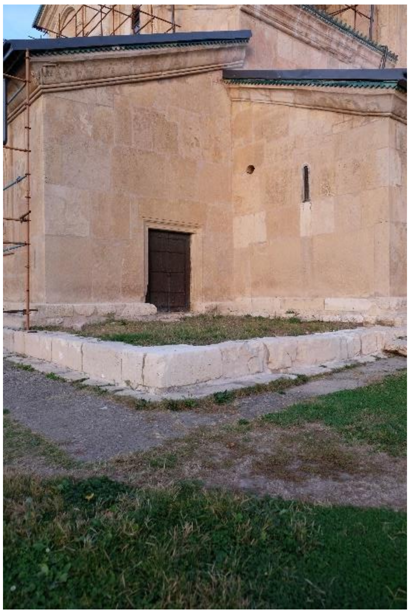


Figure 15: view of the south-west corner of the church

A.2 – OUTER LEAF OF EXTERNAL MASONRY WALL

As described above, the building rests on a stepped stone plinth that connects the construction with the terrain.

Above this socle, the wall structures are made of 'rubble masonry'. This last is a multi-leaf masonry wall, composed of two parallel walls, themselves made of large blocks of warm yellowish limestone, spaced to form a void, with variable width, filled with a lime-based conglomerate. These external walls are connected to the roofs by cornices slightly overhanging.

The plinth, the external walls and the upper cornices underwent major restoration works between 2013 and 2019 and are now in good condition except for part of the abovementioned cornices, due to local water run-off and infiltration from the roofs.

Below is a summary, of the main interventions carried out between 2013 and 2019 on the facilities under review, based on the description and documentation in the report "*Architectural Rehabilitation of the Church of Virgin at Gelati Monastery*" FINAL REPORT, 2013-2018. For a more detailed description of the work carried out refer the aforementioned document.

A.2.1 - Rehabilitation of cornices and façades

- Shortening of existing wooden rafters

At the initial stage of the working process the wooden rafters, which being in direct contact were damaging the cornice stones, were shortened.

- The treatment of the stone surface with BenzalkoniumChloride

The entire perimeter of the cornice was treated with Benzalkoniumchloride against the micro flora. The treatment has been repeated twice during the reporting period.

- Reconstruction of damaged cornices with stone

Preparation of existing cornice for fixing new stone details; Drilling holes for anchoring and preparation of stainless-steel anchors; The exact points for the anchoring were determined. The holes for anchoring have drilled, cleaned with air jet and treated with acetone solution. Stainless steel anchors were prepared, cut in individual size and bent with appropriate degrees. Diameter of holes -14mm, diameter of anchors -12mm, depth 15-30cm.

- Fixation of stainless-steel anchors with a two-component glue

Stainless steel anchors were fixed in the prepared holes with the two-component glue

- Production of new details from stone for cornice reconstruction

The stone details compatible with cornice stones for each specific section were individually prepared. Holes for anchoring were drilled, surface treated with special hammer and fixed with the lime mortar. The proportion of the lime mortar: 1 share of lime, 1 share of quartz sand, 1 share of black sand (thick fraction), 1 share of pozzolana.

- Fixation of new stone details on existing cornice

Adjusted new stone details, were fixed to the existing cornice and stainless-steel belt frame by the fork type anchors. For this procedure the anchoring holes with diameter 6mm and 10 mm were prepared and cleaned by air jet and acetone mixture. Fork type anchors were produced from stainless steel stem of 4mm and 8mm diameter. The anchoring had been conducted with the use of two-component glue (epoxide).

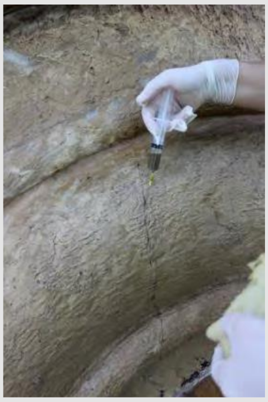
- Preparation of Cornice's stones surfaces for further reconstruction with a mortar

The reconstruction of the relatively less damaged cornice stones was done by lime mortar with following composition: 1 share lime, 1 share quartz sand, 0,5 share marble powder, 0,5 share black sand, 1 share pozzolana, 0,5 share white stone peddles of middle fraction and fibrous material. In some cases, to gain higher durability, the stainless-steel frames had been arranged inside the plaster.


- Injection

At the final stage, joints between the stones were injected. The injection mixture proportion was: 1 share pozzolana, 2 shares natural hydraulic lime *NHL5.*





- Preparation of anchor holes (West façade)


- Cleaning of spaces between stones (Western Façade)

- Injection process (Western Façade)

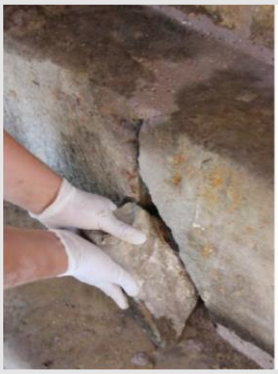
- Rehabilitation of missed part of the cornices with stainless metal and fibre glass and lime mortar (Western Arm)

A.2.2 – Conservation works of socle

- Treatment with biocide

- Mechanical cleaning

- Unification process of fragmented stone details by epoxide rubber



- Damaged and rehabilitated socle

- Damaged and rehabilitated socle

A.3 – ROOFS

For a more detailed review of the state of the roofs, refer to the "*Report in the mission and preliminary suggestion on the reasons for the water infiltration and the initial recommendations for the protection from water infiltration*". Which documents the "*Mission carried out in Kutaisi (Georgia) at Gelati Monastery by Ugo Tonietti and Sara Stefanini, from June 25th until June 29th, 2021.*" However, to allow a correct interpretation of the hygrometric state of the building, it is important to highlight that:

- At the time of the survey, almost all the roof pitches were covered with temporary metal sheet roofs equipped with perimeter eaves and downspouts for rainwater drainage. The only roofs without protective coverings were those of the central dome (env. 16) and the two pitches over the loggias above the aisles (*figures 16, 17, 18* and *19*). Therefore, given the presence of the temporary roofing, in progress seepage at the time of the inspection is excluded.

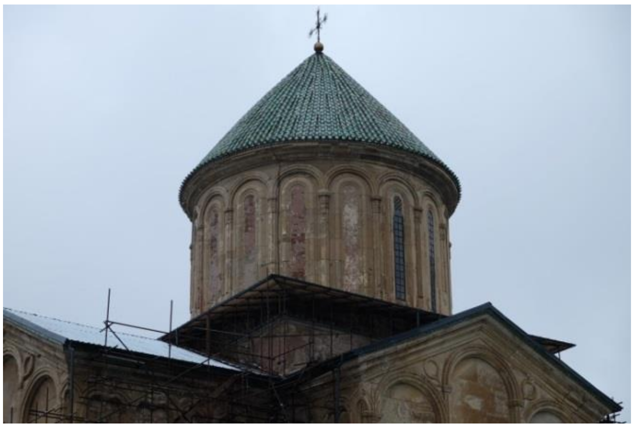


Figure 16: roof of the central dome, without temporary covers

Figure 17: roof of the southern aisle, without temporary covers

Figure 18: roof of the southern aisle, without temporary covers

Figure 19: roof of the northern aisle, without temporary covers

– At survey, all the temporary coverings, except for those over the "spandrels" of the drum, were built immediately above the tiled roof coverings, hence without a significant passage of air between the tiles and the overlying metal sheet (*figures 20, 21, 22* and *23*). This may result in a delay of the drying process, through evaporation, of any water that could have entered below the roof covering as a result of past infiltrations. Similarly, it could also lead to condensation on the underside of the temporary corrugated sheet coverings themselves. Ultimately, it is important to highlight that the very presence of glazed tiles (thus, not very permeable) constitutes an obstacle to the drying process of the underlying structures and can cause interstitial condensation phenomena when particularly high levels of humidity in the substrate material may occur.

Figure 20: structure of temporary roofing shelter, elevated on roofing tiles layer

Figure 21: structure of temporary roofing shelter, elevated on roofing tiles layer

Figure 22: temporary roofing leaning against roofing tiles layer

Figure 23: detail view of cornice and the eaves of a temporary roofing leaning against roofing tiles layer

A.4 – OPENINGS

The five entrances to the church (one on the western façade, two on the northern one and other two on the south) are equipped with wooden and metal doors of fine workmanship. When closed, these doors completely interrupt the exchange of air with the outside (except for a modest passage along the perimeter edge).

All windows are fitted with well-made wooden frames and glass panes or with an 'anti-animal' net and a protective external shutter. Consequently, with regards to air exchanges with the exteriors, we can have: completely closed windows with glass panes, completely permeable windows with mesh panels and external shutters, and mixed windows with one part glass and one part comprising a mesh and shutter (*figure 24*).

Internal openings are equipped with various type of fixtures (wooden made, metal gratings or curtains) that may or not prohibit air circulation.

The detailed list of fixtures and their condition at the time of the survey are shown in Sheet 1.

Figure 24: view of three windows overlooking the transept: the middle one only glazed, while equipped with 'anti-animal' net and a protective external shutter the side ones

B – SURVEY

The investigation of the hygrometric state of the surfaces was carried out with portable instrumentation based on the variation of the electrical conductivity of the material and variation of the dielectric constant. At the same time, the wall surface was surveyed with a high-precision infrared (384 × 288 pixel) camera which displayed the different temperatures on the surface and, therefore, could indirectly indicate possible wet areas. Finally, Merck's immediate response colorimetric tests (MQuant, Nitrates and Sulphates) were used to assess the extent and distribution of surface hygroscopic salts. The above investigations informed the localisation of the samples' collection which were then subjected to specific laboratory examination. The results of the tests and the position of the preliminary sampling are referred on Sheet 2.

B.1 – HYGROMETRIC SURVEY AND HYGROSCOPIC SALT TEST

As mentioned above, instrumental hygrometric measurements were carried out using both the ohmic method and the capacitive method for comparison of the acquired data. In the first case, the possible presence of soluble salts directly affects the measurement by altering the electrical conductance of the material; in the second case, any salts are detectable only if they are deliquescent. It should be noted that the instrumental hygrometric survey, regardless of the method of measurement, provides information on the hygrometry of the surface layer (to a depth of a few centimetres) of the structures, discounting the causes of moisture itself (capillary moisture, hygroscopicity, etc.). Simultaneously to the hygrometric survey, the possible presence of hygroscopic salts on the surfaces analysed was verified with semi-quantitative colorimetric tests with immediate response by Merck. These tests are performed by contact with surfaces, thereby the presence and severity of any presence of nitrates and sulphates is detected with considerable accuracy. The measurements were carried out on 6th, 7th, 8th and 9th November.

Specifically, the areas measured and the climatic conditions at the time of the measurements were:

- Day 6th November (good weather):

    Env. 15 (h 110 cm above floor) T = 18.2 °C; RH = 48.7%

    Envs. 3 and 4 (h 110 cm above floor) T = 16.7 °C; RH = 55.4%

- Day 7th November (foul weather):

    Env. 15 (h 110 cm above floor) T = 14.2 °C; RH = 61.0%

    Envs. 7, 8 and 3 (h 110 cm above floor) T = 16.7 °C; RH = 55.4%

- Day 8th November (good weather):

  Env. 15 (h 110 cm above floor) T = 17.0 °C; RH = 56.1%

  Env. 15 (vault) T = 17.4 °C; RH = 54.7%

- Day 9th November (good weather):

  Env. 15 (h 110 cm above floor) T = ---; RH = ----

  Env. 15 (vault) T = 16.6 °C; RH = 64.0%

B.1.1 – Lower portion of walls (reachable parts)

The instrumental survey results reflect a quite heterogeneous situation characterized by a modest presence of moisture in the interior parts of the building and an increased surface humidity along the perimeter walls. This is evidently a quite ordinary distribution of moisture (current or past) contributions from outside, fed by water dispersed around the building. Nonetheless, the gauged moisture has rarely reached high levels which are typical of aggression by infiltration or capillary rise in progress. This indicates a current probable prevalence of the hygroscopic component over the capillary or infiltration component. To assess the presence of hygroscopic salts, several semi-quantitative-immediate-response-tests were performed where the instrumental survey has indicated as wet. The outcomes span from positive to very positive for nitrates, whereas in the case of sulphates it varies from very positive to negative (*figures 25 and 26*). Conversely, results were negative in areas found to be dry during the instrumental survey.

Figure 25: test N8 (env. 6)

Figure 26: Test S2 (env. 7)

B.1.2 – Vault and wall of the west arm (env. 15)

Given the geometry of the surfaces surveyed, measurements have been performed with a regular geometric grid as reference (Sheet 2). In this instance the instrumental hygrometric survey gave extremely differentiated results with some areas dry and others very wet. This distribution is generally indicative of localised moisture inputs caused by local and occasional events. Specifically, the north side of the vault is essentially dry with only a few spots of moderate and circumscribed humidity. The situation on the south side is much more serious, with localised very high humidity values, especially (but not only) in the area immediately above the haunch of the vault (*figure 27*).

The areas found to be wet at the north side of the vault, are characterised by a varying presence, from abundant to very abundant, of both nitrates (**N19**, **N20**, **N21**, **N22** and **N23** tests), and sulphates (**S6** and **S7** tests). Conversely, sulphates are either absent or present in small quantities in 'dry' areas (**N24** and **N25** tests). On the south side of the vault, the nitrates were extremely abundant in those areas found wet (**N3**, **N14**, **N15**, **N16**, **N17** and **N18**), while, instead, have not been detected high concentrations of sulphates (*figure 28*).

Figure 27: hygrometric measurements by portable instrument

Figure 28: Nitrates and Sulphates check

A nitrates' check has been carried out also for a portion of the exterior cornice which displayed degradation phenomena. Results showed values varying from positive to extremely positive (**N29** and **N30** tests; *figures 29 and 30*).

Figure 29: foreground of cornice

Figure 30: Nitrates check on the cornice (test N29)

Investigations were also performed on the upper part (near the vault) of the western external wall. The instrumental survey indicated a situation which corresponds to the condition of the vault, namely, wet surfaces on the southern side of the structure and dry or mildly wet on the remaining part of the wall.

At all spots gauged, nitrates have been found abundant (**N26**, **N27**, **N28**).

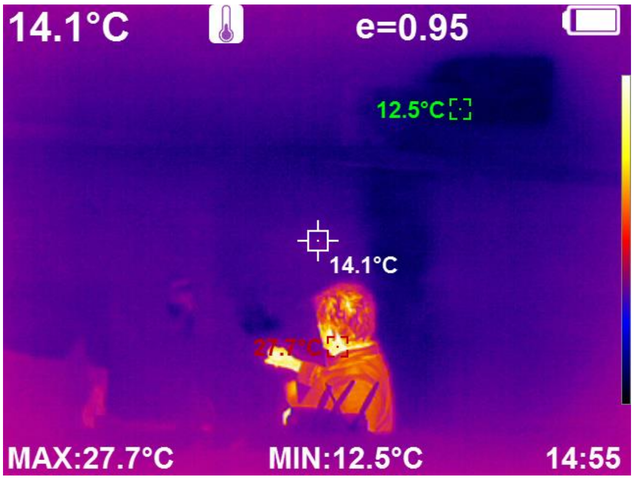
B.2 – THERMAL IMAGING

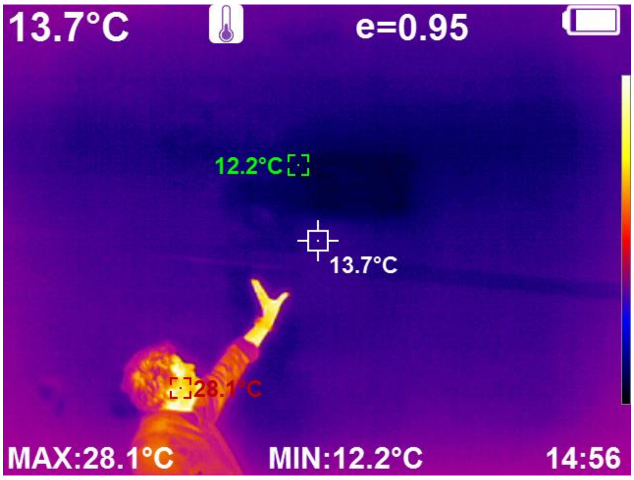
A thermographic survey shows the thermal radiation emitted by any object with a temperature above the absolute zero (-273.14 °C). Therefore, using a special thermal camera the heat distribution is portrayed on a 'photo' called thermogram.

Correspondingly, the different temperatures measured are characterised, in the thermogram, with different colours according to a representative chromatic scale.

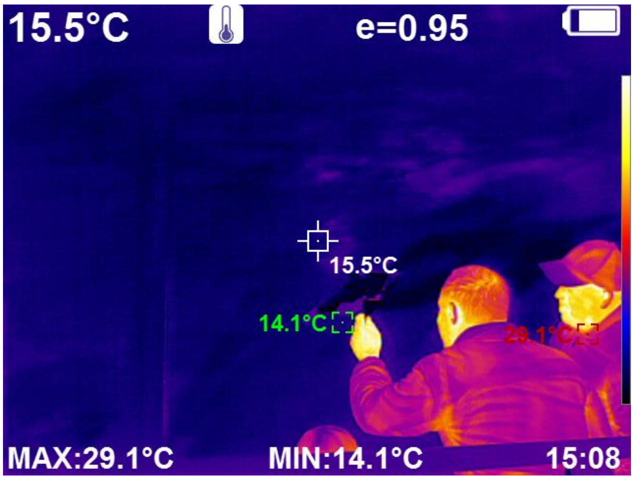
Within a hygrometric survey on structures, the thermal imaging enables the identification of wet areas, since, at specific conditions (for instance a significant evaporation of the wet surface), can be colder than dry areas.

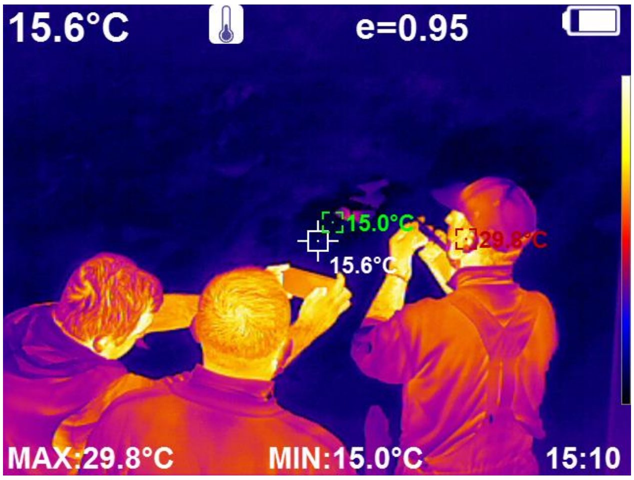
Specifically, the thermal imaging surveys did not reveal any areas subject to particularly strong evaporative flows (and therefore identifiable as colder), with the sole exception of the areas that were deliberately wetted during the work to secure the plaster on the vault of the north wing of the church, which was being carried out at the same time as the thermal imaging surveys (*figures 31, 32, 33* and *34*).





Figures 31 and 32: darker areas correspond to colder ones due the presence of water used when safeguarding the vault plasters





Figures 33 and 34: darker areas correspond to colder ones due the presence of water used during safeguarding operations on the vault plasters in progress

B.3 - LABORATORY STUDIES

The samples of material to be subjected to laboratory analysis were taken at significant points of the structures under examination, specifically identified on the basis of the results of the preparatory instrumental hygrometric survey. Obviously, sampling was carried out in areas free of decorative elements and in agreement with the monument's managers and the restorers on site.

The sampling has been performed with low-speed drill equipped with masonry drill bits and in collaboration with the restorers' team which was securing the decorative elements of the west vault. The specimens collected were stored in sealable polyethylene containers in order to be transported and stored, pending analysis.

A total of 31 samples of material were taken. All specimens were subjected to laboratory water content measurement, under as the same conditions as the sampling, and equilibrium humidity determination. Based on the above analysis, 18 samples were identified for the determination of the ion content of the most common soluble salts: chlorides, nitrates and sulphates.

Specifically, sampling was carried out at the following points (see Sheet 2 for the numbering of the environments and the location of the sampling points):

- Point **A**: environment 2, on the side of the north entrance (*figure 35*).
- Point **B**: environment 6, north side of the apsidal hemicycle (*figure 36*).
- Point **B'**: environment 6, north side of the apsidal hemicycle (efflorescence; *figure 36*).
- Point **C**: west wing vault, south side (*figure 37*).
- Point **D**: west wing vault, south side (*figure 38*).
- Point **E**: west wing vault, north side (efflorescence; *figure 39*).

- Point **E’**: west wing vault, north side (efflorescence; *figure 39*).
- Point **F**: sample of masonry stone (*figure 40*).
- Point **G**: east wing vault, south side and below the roofing tiles (*figures 41, 42* and *43*).

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*Figure 35: Point **A**, environment 2, on the side of the north entrance*

*Figure 36: Point **B**, environment 6, north side of the apsidal hemicycle; point **B’**, efflorescence*

*Figure 37: Point **C**, west wing vault, south side*

*Figure 38: Point **D**, west wing vault, south side*

*Figure 39: Points **E** and **E’**, west wing vault, north side (efflorescence)*

B.3.1 – Method of analysis

The measurements regarded the dried mass of specimens.

In addition, the volume of a sample was gauged since, being considerably light, it can be interesting, for the sake of the study, to express the water content referred in volume. Laboratory results are reported on Table 1, while the localisations of the sampling are on Sheet 2.

– Determination of water content

Water content assessment was completed complying with UNI EN 11085. Each sample has been placed on Petri dishes (made of borosilicate glass), weighed with a precision scale of 200 g range and 0.1 mg resolution. Subsequently, they are dried in a thermostatic electric oven at 105°C and ventilated at very low speed until constant mass is reached. Accordingly, the samples are weighed a second time and, consequently, the water content is determined.

*Figure 40: Point **F**, sample 32*

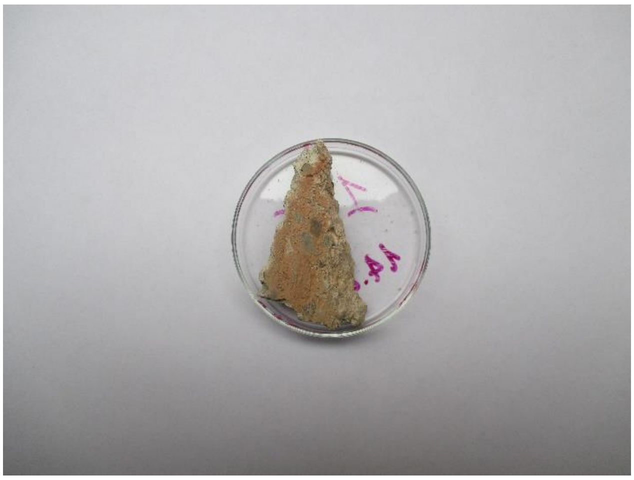


*Figure 41: Point **GA**, sample 29, layer for tiles nailing*

*Figure 42: Point **GB**, sample **30**, layer for tiles nailing*

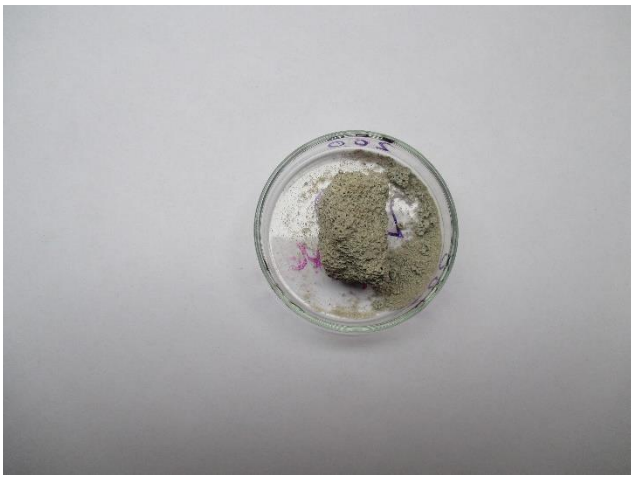


*Figure 43: Point **GB**, sample **31**, layer on the back of the vault*

– Determination of the equilibrium water content at predetermined condition

Dried samples are placed in a temperature/humidity chamber set with parameters reported on the summary sheet (relative humidity RH 75 %, temperature T 18 °C) and with circulating air to reach constant mass. Hence, the samples are reweighed, and the new water content is gauged.

– Determination of ion content of soluble salts

The assessment was performed by a wet process.

For each specimen, solutions with double-distilled water at different concentrations have been prepared. This to fall within measurement ranges of methods subsequently used, otherwise the expected values would have been difficult to assess a priori.

- chlorides have been measured by a titrimetric method with Merck reagents
- nitrates have been determined by a colorimetric method with Merck reagents
- sulphates have been measured by a titrimetric method with Hanna reagents

B.3.2 – Results assessment and interpretation criteria

The hygrometry is assessed against equilibrium humidity (75 % RH), in accordance with the exposition gap between on site and laboratory conditions. This indicates the hygrometric dynamism of the material with the environment without rising damp or infiltrations. Thus, providing a representation of the vapour exchange between the material and the environment.

Generally, if the water content, at sampling, and equilibrium humidity are low, the specimen can be considered essentially dry and 'clean' (namely without concerning amounts of hygroscopic salts). Conversely, if the equilibrium humidity, gauged in laboratory, is clearly lower than water content, the excess of water can be attributable to causes as capillary moisture and/or infiltration.

High and similar values of both equilibrium humidity and water content are ascribable to hygroscopic phenomena, specifically the porous structure and /or salt hygroscopicity. The latter case is the one which, overall, concerns the most because it may raise fears of crystallisation/solution related phenomena in relation to changes in relative air humidity.

B.3.3 – Analysis results

The results of the determinations are shown in Table 1.

1	2	3	4	5	6	7	8	9	10	11	12	13
sampling point	**sample number**	**sampling height on local floor**	**sampling depth (from wall surface)**	**water content % of dry mass**	**equilibrium moisture content at Rh 75 %, T 18°C, % of dry mass**	**nitrate ion (NO_3^-) % of dry mass**	**chloride ion (Cl^-) % of dry mass**	**sulphate ion ($SO_4^{=}$) % of dry mass**	**material**	**sampling notes**	**sample aspect**	**laboratory notes**
	n	m	cm	%	%	%	%	%				
A	1	0.58	0-5	7.30	4.97	**2.4**	**0.47**	**1.8**	mortar	joint	powder	presence of a significant quantity of scarcely capillary inert
	2	“	5-10	9.55	5.08	**1.1**	**0.30**	**1.0**	mortar + stone	afterwards stone, stop of sampling	powder	presence of a significant quantity of scarcely capillary inert
A	6	0.85	0-2	3.32	**3.61**	**1.4**	**0.30**	0.2	mortar		powder	presence of moderate quantity of scarcely capillary inert
	7	“	2-5	3.60	3.34	**1.5**	**0.35**	**0.7**	mortar		powder	presence of a significant quantity of scarcely capillary inert
	8	“	12-20	4.01	2.53	/	/	/	mortar	afterwards void	powder	
	9	“	20-30	4.65	2.58	**0.8**	**0.30**	**0.4**	mortar		powder	
A	3	1.10	0-3	2.78	2.79	**1.3**	**0.35**	0.3	mortar	joint	powder	presence of a significant quantity of scarcely capillary inert
	4	“	3-9	1.51	1.46	**0.55**	0.08		mortar + stone		powder	presence of moderate quantity of scarcely capillary inert
	5	“	27-30	3.42	2.17	**0.45**	0.10	**0.6**	mortar		powder	
B	11	1.65	0-2	1.13	1.05	0.03	<< 0.01	0.3	mortar		powder	presence of a very significant quantity of scarcely capillary inert
	12	“	2-8	2.33	1.12	**0.55**	0.07	0.2	mortar		powder	presence of a significant quantity of scarcely capillary inert
	13	“	8-20	3.31	0.90	/	/	/	mortar	afterwards stone?	powder	
	14	“	20-25	5.24	1.03	0.27	0.08	0.2	mortar		powder	

STUDIO ING. I. MASSARI CORSO TRIESTE 123 - ROMA LABORATORIO	**Sampling at Gelati Monastery GEORGIA**	**Sampling date: 10.11.2021**	**Table N.° 1**	**Schedule N°. 1**

1	2	3	4	5	6	7	8	9	10	11	12	13
sampling point	**sample number**	**sampling height on local floor**	**sampling depth (from wall surface)**	**water content % of dry mass**	**equilibrium moisture content at Rh 75 %, T 18°C, % of dry mass**	**nitrate ion (NO_3^-) % of dry mass**	**chloride ion (Cl^-) % of dry mass**	**sulphate ion ($SO_4^=$) % of dry mass**	**material**	**sampling notes**	**sample aspect**	**laboratory notes**
	n	m	cm	%	%	%	%	%				
B'	10	1.4-1.6	sup			35	< 0.01	**1.0**	efflorescence	on one side of the altar	efflorescence	not entirely water soluble **yes,** effervescing with HCl.
C	15		0-2.5	12.97	2.97	**0.55**	0.02	**0.4**	mortar	joint	powder	presence of a small quantity of scarcely capillary inert
	16		2.5-7.5	15.00	3.24	0.12	<< 0.01	0.1	mortar	joint	powder	presence of a significant quantity of scarcely capillary inert
	17		7.5-12.5	18.42	3.86	/	/	/	mortar	joint	powder	
	25		12.5-17.5	18.73	4.01	/	/	/	mortar		powder	
	26		17.5-25	16.28	3.33	/	/	/	mortar		powder	
	18		27-35	19.19	3.99	0.03	<< 0.01	0.2	mortar	afterwards void	powder	presence of a small quantity of scarcely capillary inert
D	19		0-3	1.55	1.46	**0.40**	0.02	0.2	mortar	joint	powder	
	20		3-8	4.74	1.34	0.30	< 0.01	< 0.1	mortar	joint	powder	
	21		8-13	1.60	0.76	/	/	/	mortar + stone?		powder	
	22		13-20	1.82	0.28	/	/	/	mortar? stone?		powder	
	23		20-30	1.46	0.56	< 0.01	<< 0.01	0.2	stone		powder	
	24	"	30-40	1.49	0.52	/	/	/	stone	afterwards void	powder	

STUDIO ING. I. MASSARI **CORSO TRIESTE 123 - ROMA** **LABORATORIO**	**Sampling at Gelati Monastery** **GEORGIA**	**Sampling date: 10.11.2021**	**Table N.° 1**	**Schedule N°. 2**

1	2	3	4	5	6	7	8	9	10	11	12	13
sampling point	**sample number**	**sampling height on local floor**	**sampling depth (from wall surface)**	**water content % of dry mass**	**equilibrium moisture content at Rh 75 %, T 18°C, % of dry mass**	**nitrate ion (NO_3^-) % of dry mass**	**chloride ion (Cl^-) % of dry mass**	**sulphate ion ($SO_4^{=}$) % of dry mass**	**material**	**sampling notes**	**sample aspect**	**laboratory notes**
	n	m	cm	%	%	%	%	%				
E	27		sup			35	< 0.01	**2.0**	efflorescence	on the vault	efflorescence	not entirely water soluble no effervescing with HCl.
E’	28		sup			45	< 0.01	**1.0**	efflorescence	on the vault	efflorescence	not entirely water soluble no effervescing with HCl.
F	32			0.38		/	/	/	stone	the same stone of the masonry	fragment	absorbed water: 7.53 % of its dried mass (entirely wet sample, dipped 2/50 of its height, under bell glass)
GA	29			13.8	3.33	/	/	/	mortar	layer for tiles nailing	fragment	
GB	30			12.9	3.34	<<0.01	< 0.01	0.1	mortar	layer for tiles nailing	fragment	as the sample 30, but smaller
GC	31			23.75	16.58	< 0.01	0.03	0.2	cellular concrete	layer on the back of the vault	fragment	specific dry mass about 670 kg/mc, then volume water content, (at sampling moment) about 16 %
Note: abundant scarcely capillary inert of not thin size can simulate a smaller water content (in respect of similar samples without)												

STUDIO ING. I. MASSARI **CORSO TRIESTE 123 - ROMA** **LABORATORIO**	**Sampling at Gelati Monastery** **GEORGIA**	**Sampling date: 10.11.2021**	**Table N.° 1**	**Schedule N°. 3**

Laboratory assessments have indicated:

- For sampling point **A**, detection of rising damp at 58 cm (above the floor) with copious presence, both on surface and in depth, of hygroscopic salts. Rising damp is nearly absent at 85 cm and not detected at 110 cm, but at both heights hygroscopic salts are present (mainly nitrates), with accentuation in the most superficial samplings.
- For sampling point **B**, damp increases mildly from the wall surface (dry) to deeper in the wall (towards the exterior of the building) and low presence of hygroscopic salts. This last information is quite surprising since it was identified a significant presence of salt efflorescence, with high concentration of nitrates, near the sampling point (sampling point B'; sample number 10).
- For sampling point **C**, abundant damp which increases from the wall surface (12.97 % of water content) to the inner masonry (19.9 % of water content), namely towards the exterior of the roof. Sulphates are significant only at surface level. During sampling operations, it has been found a gap of approximately 35 cm; a similar void was found at about 40 cm in depth in the other sampling point on the vault (**D**).
- For sampling point **D**, substantial absence of moisture with modest presence of nitrates only at surface level. As for point C, sampling was executed in the joint between two stone blocks, however, the nature of the material collected is uncertain and perhaps comprising abundant stone powder which is considerably less capillary than mortar joints.
- Unusual presence of conspicuous efflorescence with a very high concentration of nitrates was observed on areas, of the vault intrados, not subjected to infiltrations (sampling points **E** and **E'**; sample number **27** and **28**).
- For sample point **F**: the sample **32** was analysed to verify the absorbent capacity of the stone. Specifically, a piece of stone of the same type as that of the wall face, after drying out in an oven, up to a constant mass, was tested for water absorption, under a glass bell, with immersion of 2/50 of its height, up to a constant mass. The total absorption was lower than expected (7.53 % of its dried mass). Also unexpected was the strong presence of nitrates (assessed by instantaneous colorimetric test).
- For sampling points **GA**, **GB** and **GC** (namely, corresponding to samples **29**, **30** and **31** which are sampled below the roofing tiles of the south-east lunette), it was observed high values of water content, at sampling, both right beneath the tiles (**GA** and **GB**) and in the underlying light screed (**GC**); in addition, hygroscopic salts were detected.

C – DIAGNOSTIC CONCLUSIONS

C.1 – Lower part of vertical structures (where measurable)

The internal structures of the church suffer from modest hygroscopic dampness which tends to increase towards external environments, namely where occurs a mild capillary rising damp which, in turn, did not rise over 1 m from the ground. Nonetheless, the instrumental hygrometric survey suggests that, by laboratory analysis, it might be detected a variation of rising damp heights at areas not subjected to sampling (for a discrete survey on rising dampness a more extensive sampling would be necessary). Furthermore, either storm water runoff from slightly overhanging roofs, defects in the roofs themselves (absence or ineffective drip trim), or windy rain, may have caused rainwater infiltrations through the joints of external masonry walls. Temporary coverings, and related water collection and channelling system (eaves gutters, downpipes, and ground drainage network), have effectively reduced water runoff on vertical surfaces of the construction, yet are not definitive measures.

Indeed, it was observed an extended presence of hygrometric salts and, primarily, damages on decorative features also in areas which, at the time of the survey, were not undergoing rising damp phenomena or water infiltrations. This witnesses past hygrometric conditions of the Church more serious than those observed during the mission.

C.2 – West vault of central nave

Damp distribution, on surfaces and in the thickness of the vault (see lab analysis results), reflects a typical (slow) drying process from top infiltration. The recent infiltration affected mainly a 3.0 m wide area around the southern vault haunch and the cornice on the western external wall. At the time of survey, the whole structure was covered with a temporary metal roofing (built in 2020) equipped with perimeter eaves channel and drainpipes to convey rainwater. Notwithstanding this, the detected hygrometric situation is severe, to wit characterised by high damp values and copious superficial presence of nitrates. Yet, the latter, resulted being poor from in depth samplings.

Infiltrations, however, must have occurred repeatedly also in the less recent past since widespread salt efflorescence have been detected in areas saved by the last infiltration.

Regardless the causes of the infiltrations (subject engaged by Eng. Ugo Tonietti and Arch. Sara Stefanini), the persistence of such a high level of moisture in the vault is not easy to justify. Assuming that the temporary coverings are well performing, namely preventing any infiltration, is likely that the water penetrated, previously, under the last roofing layer, is trapped between the stoned vault intrados and the glazed roof tiling layer which, in turn, preclude the evaporation toward the exterior (perhaps with the water for the mixture of the new screed which the roof tiles have been installed on). Results of the laboratory analysis on samples **29**, **30** and **31**, confirms this hypothesis through the measurement of high moisture contents under the roofing layer, specifically on south-east spandrel, which is currently covered with a temporary canopy, hence not subjected to new from top infiltrations. Furthermore, for what concerns the west wing vault, any possible evaporation could be additionally hampered by the temporary metal covering, which was installed directly on the roof tiling layer, thus without a sufficient ventilation gap. The abundant, yet superficial, presence of hygroscopic salts (mainly, but not only, nitrates) suggests the external contribution of clean water which, however, spread existing on structures salts (mainly in the intrados). Phenomenon testified, after all, by efflorescence observed on vault areas not experiencing in process infiltrations.

D – INITIAL INDICATIONS TOWARDS HYGROMETRIC IMPROVEMENTS OF STRUCTURES

D.1 – Lower parts of the vertical structures

The instrumental survey showed a mild capillary rising damp phenomenon along the external walls of the building. This incident is mainly caused by water on ground, water running from the roofs and the snow deposits during winter.

At the surveying time, only a modest conglomerate sidewalk protected the base of the external walls, however, it is inadequate in the instances of copious exterior water flow.

Contextually, the church is protected by provisional sheet metal coverings slightly overhanging which are equipped with appropriate eaves channels and downpipes to convey water to the sewage network outwards the building. The latter needs maintenance works, manholes cleaning, and some downpipes repositioning amongst other preservation measures. Regrettably, for years large amounts of water have been let run freely on structures as the plinth and the sidewalk from the above roofs. This, evidently, led to seepage and capillary rising damp phenomena considerably severer than the current ones.

Provisional coverings significantly reduced the amount of water that, by trickling or because of windy rain, ran on the walls’ surfaces. Essentially, the above temporary structures protect validly against possible infiltrations through the outer leaf of the external walls.

Considering what has been discussed above, and to better assess the situation as also evaluate improvement measures, is considered necessaire:

- to carry out a dimensioned survey of the floors (ground) outside the church to check the slopes of the land and identify the current surface water runoff lines.
- undertake some ground borings to study the foundations (construction techniques, type of material-s-, depth) and to assess the presumable existence of a superficial rock bank and its planimetric layout. This survey should be performed along the north, east and south fronts.
- specify the water runoff system for the permanent roofs.

Based on this information, it will be possible to evaluate possible interventions to protect the structures such as, for example

- small interventions of re-modelling of the external ground to prevent the flow of surface water towards the building;
- the restoration of the old drainage channels or the construction of new draining trenches; (not in contact with the building) to intercept surface and sub-surface water "upstream" of the church;
- the integration of the existing pavement, that is, the construction of a new pavement (or paved strip) with a suitable slope to remove water from the building and convey it to the perimeter sewage systems;
- Revision or, if necessary, reconstruction of the sewage system at the perimeter of the building, and definition of the collection points for surface water and sewage from roofs.

However, apart from any new measures to protect the building from humidity, it is an absolute priority to ensure constant maintenance of the building (e.g., of the joints between the stone blocks, with particular reference to those of the socle) and of the technical equipment that protects it (fixtures, gutters, downpipes, manholes, etc.).

D.2 – Vault and wall of the west arm

Despite infiltrations have been prevented by the installation of temporary canopies which currently protect most of the building, the Church west wing vault, and its decorative apparatus, are undergoing consequences of infiltrations occurred before the construction of the impermanent structures. Specifically, the water ‘trapped’ between the vault stoned intrados and the roofing layer made of glazed roof tiles. In addition, pre-existing hygroscopic salts, which are abundant on superficial, still impact the structures mentioned above.

Unfortunately, this unusual existence of water seems regarding also other roofs' structure (see the south pitch of the east wing of the central nave), yet with apparently lessened repercussions compared to those detected on the west wing vault.

Prescinding from future decisions regarding roofs renovation, the very current priority is to arrest the degradation process which affects plasters of the west wing vault and evacuate the excess moisture from the supportive structure. In this regard, any attempt to boost the drying process of the interiors, namely from frescoed side, must be avoided to prevent further damages, even worse than the existing ones. A forced increase of the evaporation flow through the plastered layers, indeed, might bring hygroscopic salts, present in internal layers, towards the decorated surfaces, thus causing the development efflorescence and salt sub-efflorescence which their disintegrating effects would be serious and in time prolonged. In addition, a movement of moisture may affect an immediate stress on plasters and decorative layers. Therefore, the only measure is intervening at the exteriors:

Specifically, is advisable:

- Build a new temporary covering that is sufficiently raised above the roof pitches (or raise the existing one), leaving adequate space for the subsequent work to be carried out and for plenty of air circulation. The new temporary covering will probably have to be wider than the existing one to avoid the ingress of wind-driven rain or other possible infiltrations that would affect structures without other protection systems (see subsequent work). The extent and type of the new provisional cover remain to be defined based on the indications of the team of engineer Tonietti.
- Dismantle the portion of the (existing) provisional sheet metal covering corresponding at least to the part of the vault that is still wet (west arm, south pitch)
- Remove the glazed tile covering and any underlying waterproof layers, leaving the screed underneath exposed to the air to allow it to dry from the outside.

Throughout the drying process, the state of health of the plasters must be monitored, taking the precautions that the restorers deem appropriate and necessary. Once drying is complete (the drying process can be monitored with instruments for hygrometric measurement of the materials or by taking samples for laboratory analysis), it will be possible to proceed with the restoration/stabilisation of the plasters and, subsequently, with the reconstruction of the roofs.

Generally, the above approach can be applied to all roof pitches, obviously in respect of the specific adaptations of the cases.

E – MICROCLIMATIC MONITORING

The survey showed the widespread presence of hygroscopic salts (particularly nitrates, but also sulphates and chlorides), with local high concentrations. As it is known these salts interact directly with the surrounding environment changing their physical state as the latter vary thermo-hygrometric conditions. If these parameters are particularly unstable, they may determine cyclical crystallisation processes (with low relative humidity) and deliquescence (with high relative humidity in air), which might result in harmful consequences for salts steeped materials: peeling of the painting or superficial desegregation to cite a couple.

Furthermore, during the mission Dt. Roland Isakadze highlighted the existence of potential superficial condensation on some internal walls occurred between spring and summer, deduced by the appearance of drops on the internal walls surfaces of the narthex and the aisles.

Given what is discussed above, the monitoring of the microclimatic situation in the Church is prioritising to understand the ongoing phenomena and, thus, evaluate improvement measures. The latter for both the drying phase of the structure affected by infiltrations and the subsequent phase when the drying is complete. In addition, monitoring data can inform the roofing design, to guarantee a certain microclimate in internal environments.

Acknowledged the importance of microclimatic factors for the decorative apparatus conservation, authorities and local professionals have begun, in December 2020, a monitoring project which guidelines are thoroughly portrayed in the document "MONITORING OF ENVIRONMENTAL CONDITIONS OF GELATI MONASTERY COMPLEX". It is suggested to refer to the latter for a detailed report of the in-progress monitoring.

To summarise, the data of the monitoring are:

- Duration of monitoring: 1 year (minimum)
- Data recording interval: 1 hour
- Recorded data: Relative humidity and temperature
- Calculated parameters: Absolute humidity and dew point
- Number of sensors installed:
    - *Internal sensor*: main space of the Church of Nativity of Holy Virgin (7 sensors). Chapel (4 sensors), gates (2 sensors) and narthex (1 sensor).
    - *Internal sensor*: St. George Cathedral, at altar floor (1 sensor), and the central space

(2 sensors).

- *Outdoor sensor*: south of the monastery complex, open balcony of the cells (1 sensor)

For the location of the sensors see sheet 1 where the positioning indicated in the document "MONITORING OF ENVIRONMENTAL CONDITIONS OF GELATI MONASTERY COMPLEX" has been reported.

Generally, the criteria adopted for the monitoring are broadly agreeable and given the time frame of the executed monitoring, it is considered appropriate to not move the sensors. However, the following changes are advised:

- The sensors for measuring the air parameters (temperature and relative humidity) must be positioned not too close to the wall structures (minimum distance sensor/wall 10 cm) in order not to be influenced by them. If this is not possible (e.g., in the case of sensors resting directly on shelves, folds, etc.), insert an insulating spacer (expanded polystyrene or other similar water-repellent material).
- in order to oversee any potential superficial condensation development, it is needed to record also the superficial wall structures temperature with specific probes.

  It is suggested to install three sensors for superficial temperatures at the following positions:
  - n.1 on the west wing vault
  - n.1 in environments 1 and 2, on an external structure towards north
  - n.1 in an area indicated by Dt. Roland Isakadze. Namely those with potential superficial condensation spring (either one of the env. 4, 13 and 14)
- Install a sensor to measure wind direction and intensity in the monastery area. In fact, data from even relatively nearby meteorological stations cannot be considered on this specific aspect due to the specific location of the monastery and the surrounding orography.
- The data recording interval should be reduced from 1 hour to 15 minutes.
- The analysis of the measured parameters cannot be made based on daily averages but only on the data acquired at the predetermined rate (15 minutes).
- For a correct interpretation of microclimatic data, it is essential to know the conditions under which they were recorded. Specifically, it is necessary to chronicle:
  - when the entrance door is open and when it is closed;
  - when the doors to the side chapels are open and when they are closed;

- the possible presence of a large number of visitors or worshippers (e.g. during ceremonies);
- other particular events that could influence the internal microclimate parameters, such as maintenance work, extraordinary openings, etc.

Finally, from the temperature and humidity recordings made during the mission, the indoor microclimate appears to be extremely conditioned by the external one. A similar observation is also made in the document MONITORING OF ENVIRONMENTAL CONDITIONS OF GELATI MONASTERY COMPLEX *"....Comparing the indoor and outdoor humidity data, we can say that the main factor affecting indoor humidity is the climate outside the church....*".

In order to preserve the wall paintings, especially those invaded by hygroscopic salts, it is necessary to ensure the stability of the microclimatic parameters and in particular of the relative humidity (regardless of the value); unfortunately, in the current situation this is not possible due to the multiplicity of communications with the outside world that are not forbidden to the passage of air (open or semi-open windows, doors, etc. see sheet 1).

Therefore, in addition to the changes regarding the general approach of the microclimatic monitoring in place, it would be appropriate to carry out some tests to test the effects of partial and temporary closures of at least some communications with the outside world (windows, doors to the church, etc.).

Specifically, subject to the timescales envisaged for the continuation of the microclimate monitoring carried out by the Georgian National Agency for Cultural Heritage Preservation, it is proposed for a total period of about 90 days to record the microclimate (once the acquisition system has been updated as indicated above) as follows:

- For about 30 days with the current state of the openings to the outside (see sheet 1)
- For approx. 30 days, temporarily close at least 30% of the currently open or half-closed windows (including with plastic sheets if there are no lockable windows).
- For approx. 30 days, temporarily close (including with plastic sheeting if there are no lockable windows) at least 50% of the currently open or half-closed windows.

The exact choice of windows to be closed (temporarily, for the duration of the tests only) can only be made after checking which windows are reachable and which are not (see e.g., tambour windows).

Based on the results of the above test, and subject to the number of months of monitoring still available, further tests may be planned to evaluate different ventilation schemes.

passage of air / window and door frame

REF. PLAN	TYPE	STATE
Environment 1		
1a	window	open
1b	window	open
Environment 2		
2a*	big window	closed
2b	door	closed
2c	door	open
2d	portal	closed
Environment 3		
3a	window	closed
3b	window	closed
3c	door	open
Environment 4		
4a*	small window	closed
4b	door	closed
4c	small window	closed
4d	door	open/closed
Environment 5		
5a	small window	closed
5b	entrance portal	open
5c	window	partially closed
5d	portal	open/closed
5e	door	closed
5f	entrance portal	open
5g	door	closed
Environment 6		
6a	small window	partially closed
6b	small window	closed
6c	small window	open
6d	door	open
Environment 7		
7a	portal	closed
7b	small window	closed
7c	small window	closed
7d	portal	open/closed
7e	window	closed
Environment 8		
8a	door	partially closed
8b	small window	open
Environment 9		
9a	round window	closed
9b	passage	closed
9c	passage	open
9d	window	open
Environment 10		
10a	window	partially closed
10b	window	closed
10c	window	partially closed
10d*	window	open
10e*	window	open
Environment 11		
11a*	window	partially closed
11b*	window	closed
11c*	window	partially closed
Environment 12		
12a*	window	partially closed
12b*	window	closed
12c*	window	partially closed
12d	door	closed
Environment 13		
13a	gate	open
Environment 14		
14a	gate	open
Environment 15		
15a*	window	partially closed
15b*	window	closed
15c*	window	partially closed
Environment N.I.		
N.I.a	window	open
N.I.b	window	closed

*: upper level
N.I.: NON-inspectable environment


PHOTO 6

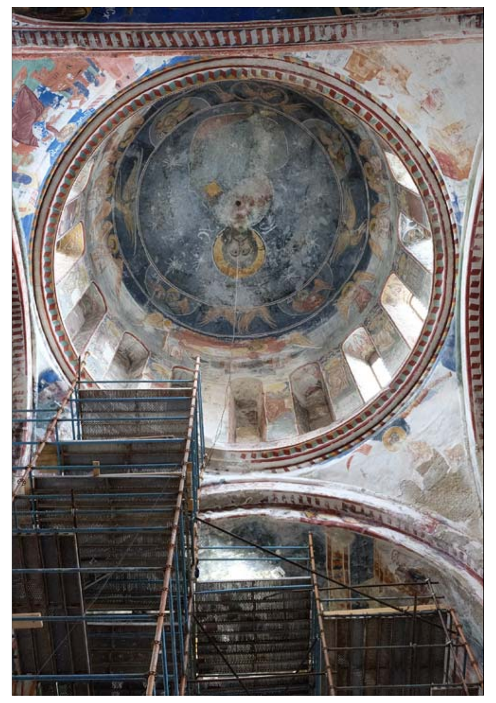

PHOTO 5


PHOTO 4


PHOTO 3


PHOTO 2


PHOTO 1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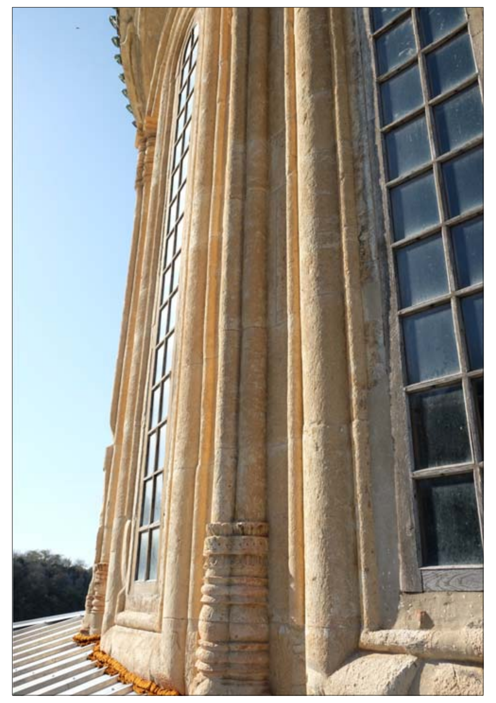
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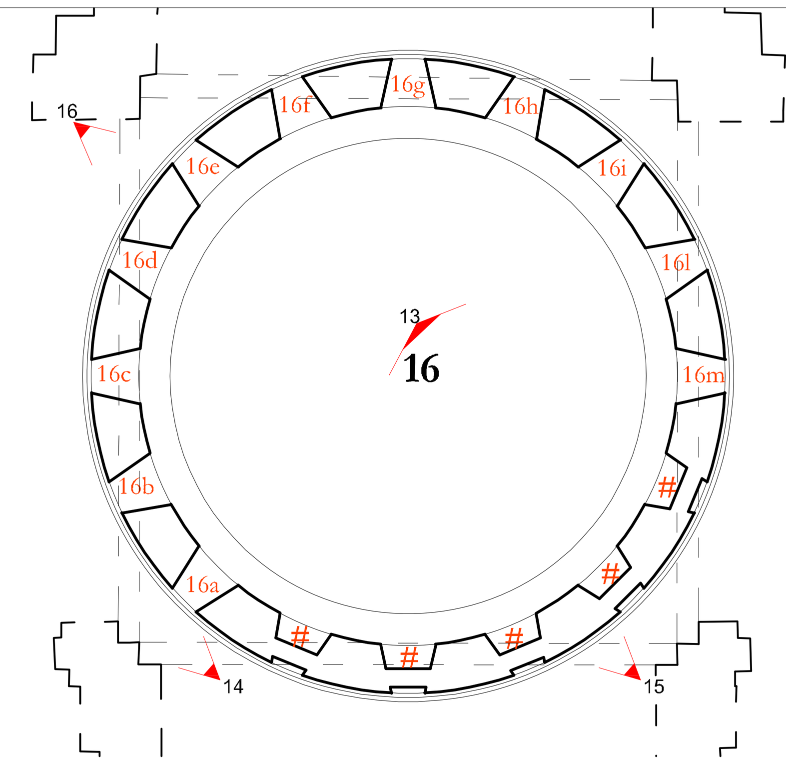


passage of air / window and door frame

REF. PLAN	TYPE	STATE
Environment 16 - Tambour		
16a	window	open
16b	window	closed
16c	window	open
16d	window	closed
16e	window	open
16f	window	closed
16g	window	open
16h	window	closed
16i	window	open
16l	window	closed
16m	window	open

: walled windows


PHOTO 15


PHOTO 16


PHOTO 7


PHOTO 8

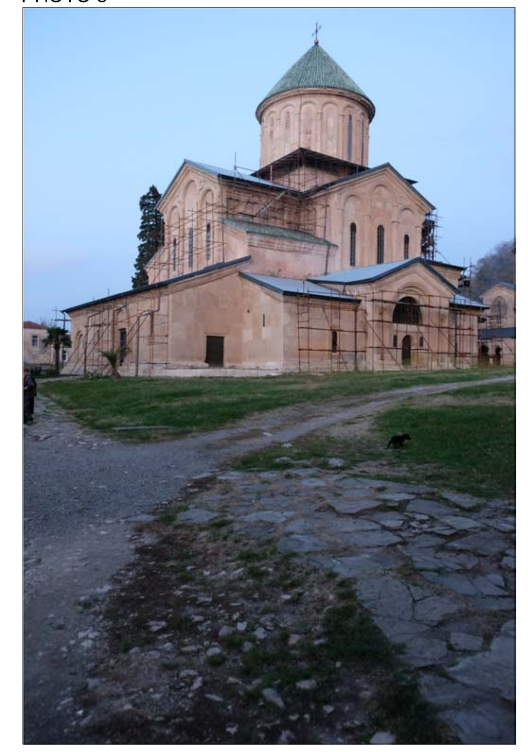


PHOTO 9


PHOTO 10


PHOTO 11


PHOTO 12

LEGEND OF GRAPHIC SYMBOLS

- open sewer manhole Ø 300
- close sewer manhole (square cover)
- close sewer manhole (round cover)
- sewer manhole Ø 300 (superior grate 50x50 cm)
- rectangular grate 60 x 40 cm (drainage passage)
- downpipe Ø 100
- drainage system (verified route)
- drainage system (indicative route)
- perimeter wrought pavement
- grassland
- point of photo

microclimatic monitoring sensors installed

- interior sensor MX1101 (bluetooth)
- interior sensor UX100-011 (usb)
- exterior sensor MX2301A (bluetooth)

Name and position of microclimatic monitoring sensors installed extracted from Monitoring of Environmental Conditions of Gelati Monastery Complex drafted by National Agency for Cultural Heritage Preservation of Georgia

DETAILS VIEW

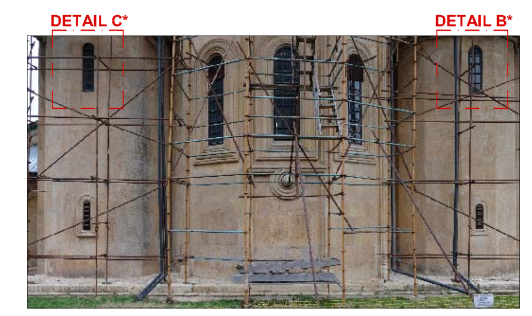


Photo 13: External view of details B* and C* non-inspectable upper rooms windows

Photo 14: External view of non-inspectable room windows above environment N.I.

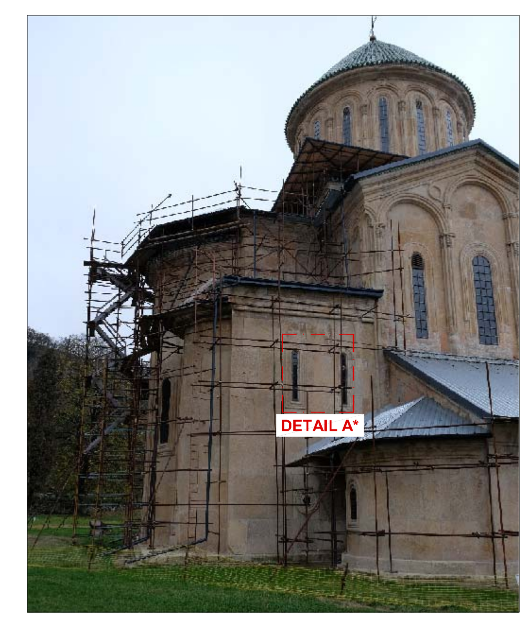
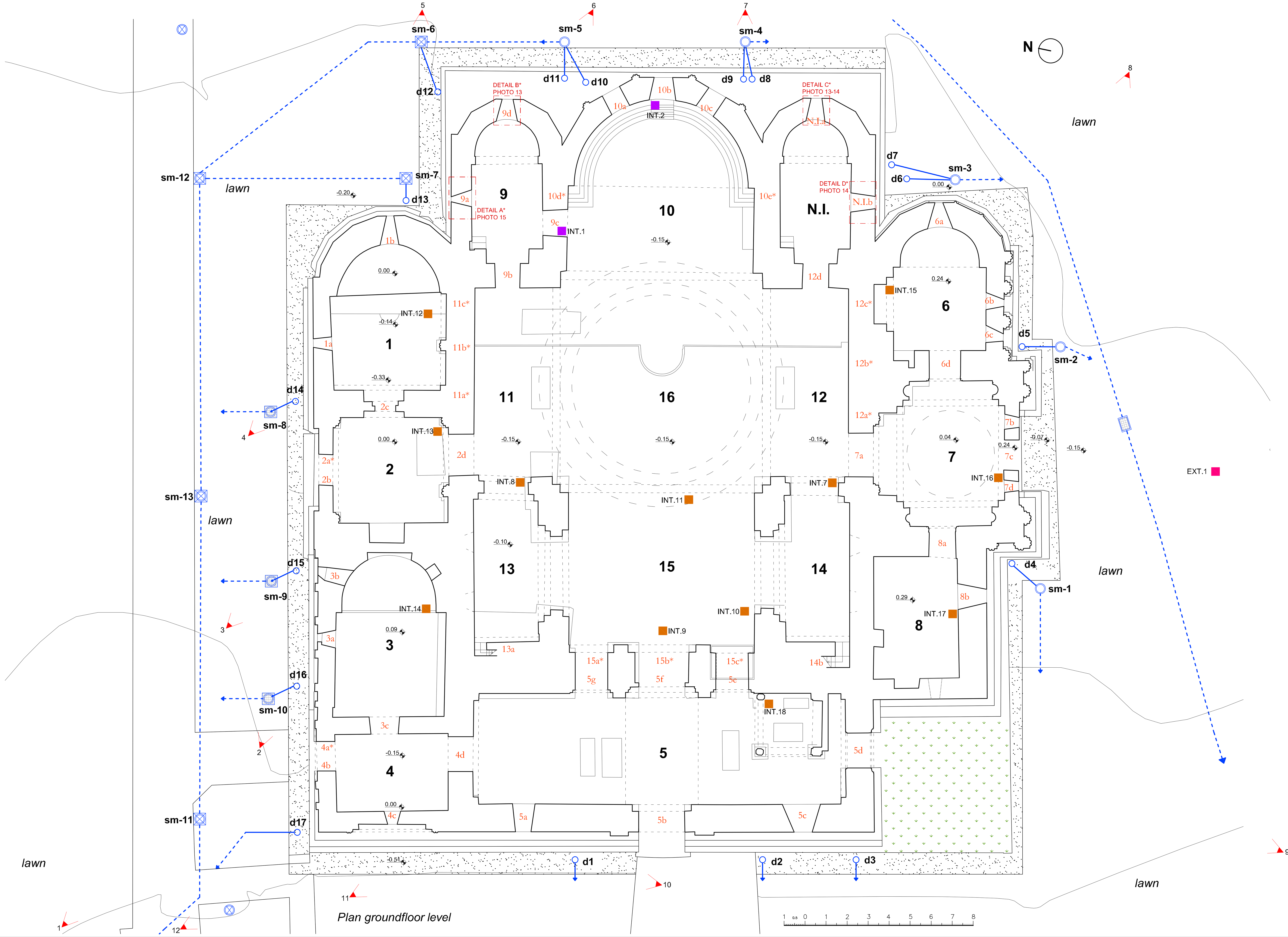


Photo 15: External view of non-inspectable room windows above environment 9



Plan groundfloor level

Gelati Monastery World Heritage Property, Georgia
Church of the Virgin

STUDIO MASSARI
CORSO TRIESTE 123-00198 ROMA

title:	date:	sheet:
CURRENT STATE	december 2021	1
	scale: 1:100	

LEGEND OF GRAPHIC SYMBOLS

- sewer manhole Ø 300
- close sewer manhole (square cover)
- close sewer manhole (round cover)
- sewer manhole Ø 300 (superior grate 50x50 cm)
- rectangular grate 60 x 40 cm (drainage passage)
- downpipe Ø 100 (d1...dx)
- drainage system (verified route)
- drainage system (indicative route)
- perimeter wrought pavement
- grassland
- point of photo
- SP-A...E sampling points
- SP-F projection of sampling point on upper floor
- SP-G external sampling point
- walls presumably subjected to superficial condensation phenomena, as indicated by dr. Roland Isakadze

LEGEND OF HYGROMETRIC SURVEY

- dry
- dry with traces of moisture
- slightly humid
- humid

NOTE: The hygrometric survey was preferably carried out on surfaces with the presence of plasters

RESULTS HYGROMETRIC SURVEY

ENVIRONMENT 1
Instrumentation survey
- **1.1** humid wall up to a height of 120 cm and slightly humid in the 120-200 cm range
- **1.2** humid wall up to a height of 120 cm
- **1.3** humid wall up to a height of 100 cm and slightly humid in the 100-170 cm range
- **1.4** humid wall up to a height of 200 cm

Nitrates test legend
- **N1** (h = 1,90 m) = positive
- **N2** (h = 2,10 m) = little positive

ENVIRONMENT 2
Instrumentation survey
- **2.1** slightly humid wall up to a height of 40 cm
- **2.2** humid wall up to a height of 70 cm and substantially dry in the 70-120 cm range
- **2.3** slightly humid wall up to a height of 150 cm
- **2.4** humid wall up to a height of 200 cm and slightly humid above 200 cm
- **2.5** slightly humid wall up to a height of 170 cm
- **2.6** slightly humid wall with presence of salts in the 120-200 cm height range

Nitrates test legend
- **N3** (h = 0,70 m) = positive

ENVIRONMENT 3
Instrumentation survey
- **3.1** humid wall up to a height of 130 cm
- **3.2** slightly humid wall up to a height of 200 cm
- **3.3** humid wall up to a height of 120 cm

Nitrates test legend
- **N4** (h = 0,70 m) = positive

Sulphates test legend
- **S1** (h = 0,70 m) = negative

ENVIRONMENT 5
Nitrates test legend
- **N5** (h = 0,60 m) = little positive
- **N6** (h = 0,70 m) = negative
- **N7** (h = 0,20 m) = very positive

ENVIRONMENT 6
Instrumentation survey
- **6.1** humid wall with high nitrate content
- **6.2** slightly humid wall near the windows

Nitrates test legend
- **N8** (h = 1,70 m) = extremely positive

ENVIRONMENT 7
Instrumentation survey
- **7.1** slightly humid wall up to a height of 200 cm

Nitrates test legend
- **N9** (h = 2,00 m) = positive

Sulphates test legend
- **S2** (h = 1,50 m) = very positive
- **S3** (h = 1,60 m) = little positive

ENVIRONMENT 8
Instrumentation survey
- **8.2** humid wall in the 120-160 cm height range
- **8.1** humid wall over 200 cm high

Nitrates test legend
- **N10** (h = 1,05 m) = very positive
- **N11** (h = 1,40 m) = very positive
- **N12** (h = 0,85 m) = very positive

ENVIRONMENT 9
Instrumentation survey
- **9.1** slightly humid wall with presence of salts in the 80-100 cm height range

Sulphates test legend
- **S4** (h = 2,10 m) = negative

ENVIRONMENT 10
Instrumentation survey
- **10.1** slightly humid wall up to a height of 200 cm
- **10.2** slightly humid wall on third step
- **10.3** slightly humid wall on third step

ENVIRONMENT 15 (BARREL VAULT SOFFIT)
Nitrates test legend
- **N13** = very positive
- **N14** = very positive
- **N15** = very positive
- **N16** = very positive
- **N17** = little positive
- **N18** = little positive
- **N19** = positive
- **N20** = positive
- **N21** = very positive
- **N22** = very positive
- **N23** = positive
- **N24** = little positive
- **N25** = negative
- **N26** = positive
- **N27** = positive
- **N28** = positive

Sulphates test legend
- **S5** = negative
- **S6** = positive
- **S7** = positive
- **S8** = negative
- **S8** = negative

OUTSIDE
Nitrates test legend
- **N29** = positive
- **N30** = positive

9* = Environment with presumably modern plastering, mostly detached
N.I. = NON-inspectable environment

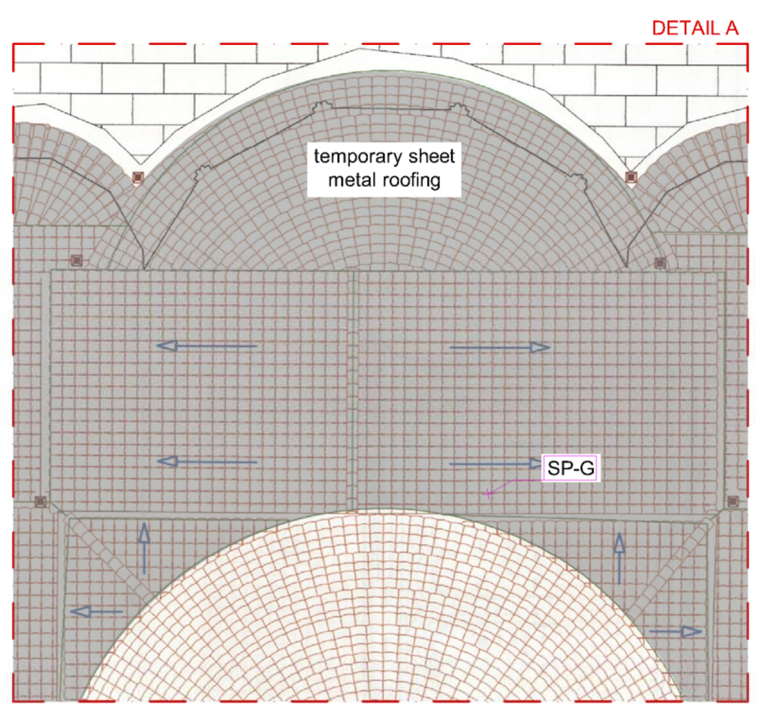



PHOTO 1


PHOTO 2


PHOTO 3

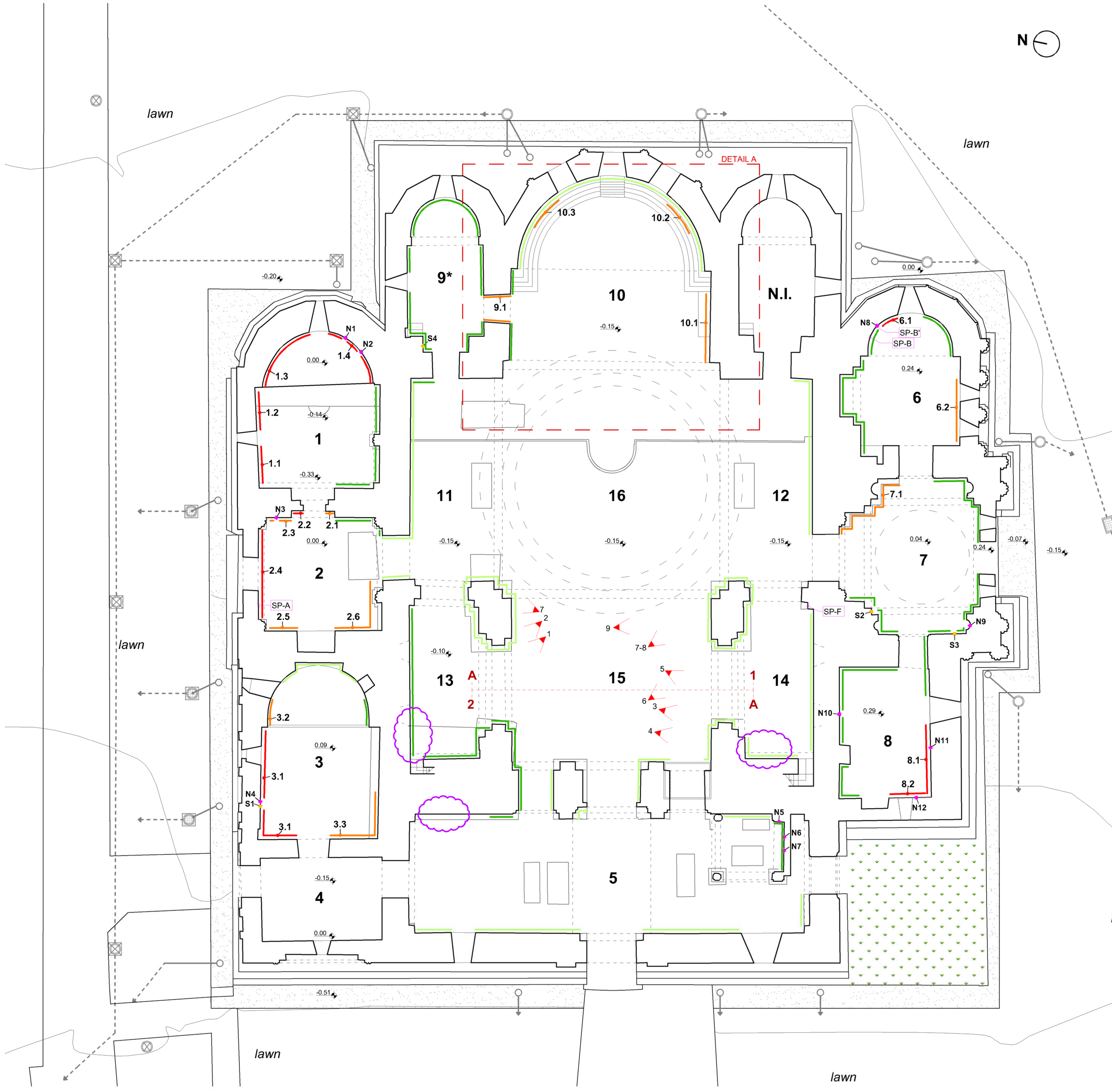

PHOTO 4


PHOTO 5

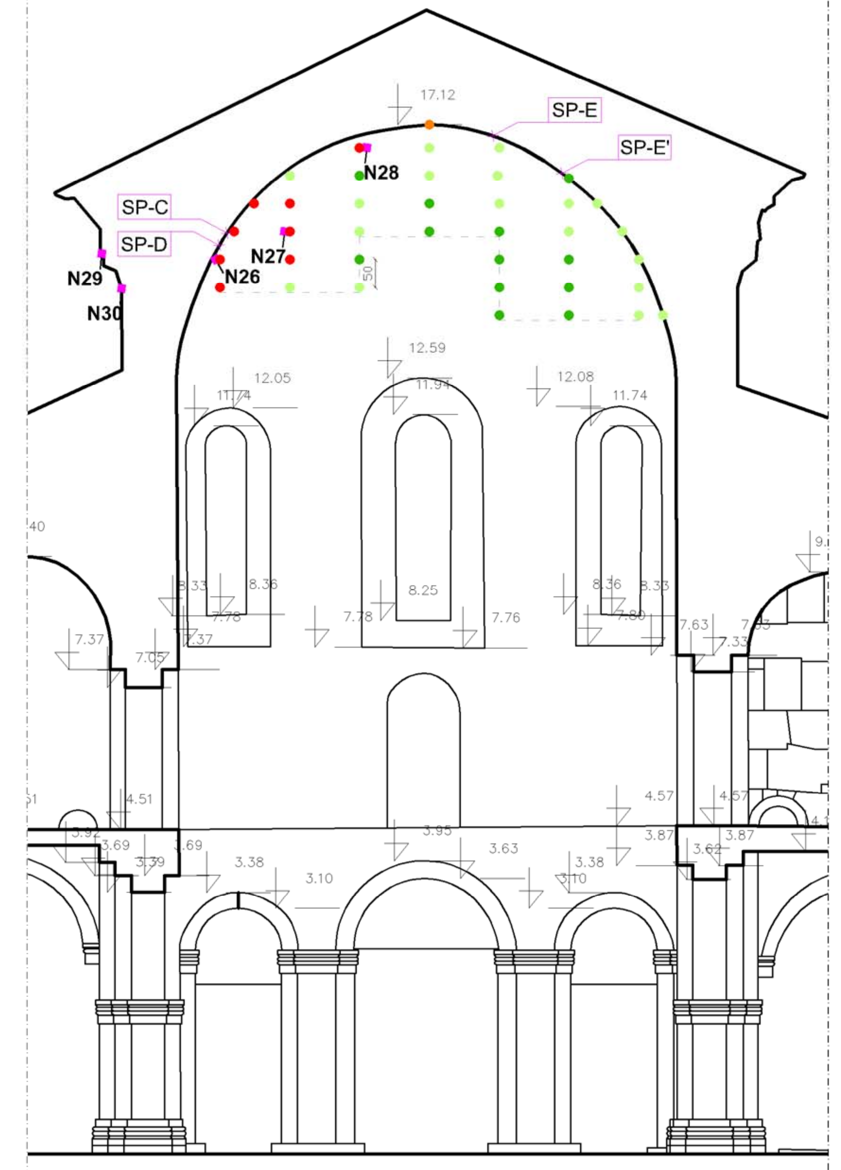

PHOTO 6


PHOTO 7


PHOTO 8

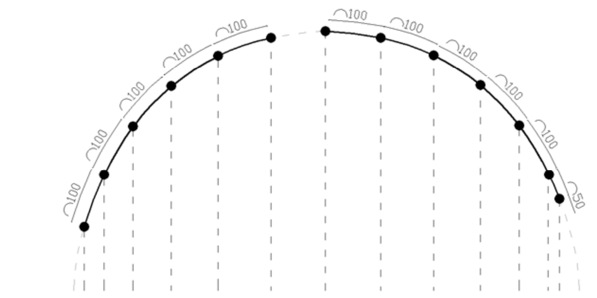


Plan groundfloor level

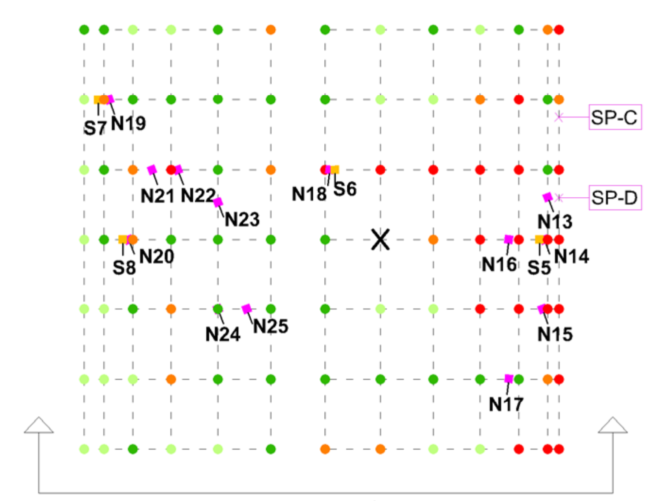


EXTRACT OF SECTION A - 2

INTRADOS PROFILE



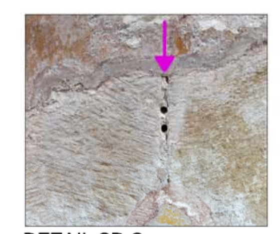
PROJECTION OF MEASUREMENTS ON A HORIZONTAL PLANE

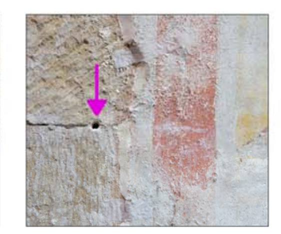


VIEW A - 1

SAMPLING POINTS

PHOTO 9


DETAIL SP-C


DETAIL SP-D

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title: **HYGROMETRIC SURVEY**
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sheet: **2**