PREVENTIVE CONSERVATION OF CULTURAL HERITAGE IN ARMENIA: A PRELIMINARY STUDY OF THE INTERNAL SURFACES IN THE GEGHARD MONASTERY

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Abstract: *In the Armenian context, most of the architectural heritages are monasteries often subjected to geological hazards and degradation of materials due to the environmental conditions. The aim of this study, in collaboration between the Ca' Foscari University of Venice and the National University of Architecture and Construction of Armenia, was a preliminary analysis of the state of conservation of the UNESCO heritage site of Geghard Monastery. Specifically, this research reports the results of the multi-disciplinary investigation on the internal stone surfaces of the caved "Proshian family room" belonging to the XIII century. In situ analyses that consisted of a careful visual survey of the stone surface, environmental monitoring, water absorption and ultrasonic measurements were conducted.The collected data constitute a starting point for monitoring the degradation phenomena, which is helpful for future preventive conservative interventions.*
Keywords: *Armenia, Geghard Monastery, preventive conservation, non-invasive analyses.*

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Received: 08.01.2024
Revised: 26.01.2024
Accepted: 17.02.2024

Introduction

Historic buildings such as Armenian monasteries are valuable architectural heritages that can often be found in secluded places. The immovable nature of these structures, their not-so-easy access, and the great variability of materials along with the geological hazards, and weathering processes to which they are subjected, could result in a challenge for their conservation and maintenance [1,2]. For this, a multidisciplinary approach should be engaged to suggest the most accurate approach according to the degradation phenomena present, the history of the monument as well as its previous restoration interventions, the building materials used, the architectural structure, etc. [3]. In particular, preliminary analyses are essential for thoroughly comprehending the heritage situation, aiding in understanding its development over time and its protection and prevention of future damages. These analyses, which should always be carried out, establish the fundamental groundwork upon which conservation and restoration works should be constructed, thereby guaranteeing the preservation of the cultural heritage.

The Geghard Monastery

Due to the high seismic activity to which Armenia is subjected, Geghard monastery was restored a lot of times, with also the total reconstruction of some parts, indeed, to this day, little remains of the original monastic complex [4].

In accordance with Mery Danielyan, one of the restorers that worked in Geghard [5], in the last fifty years, large-scale restoration works were carried out, comprehending the closing of cracks present in the carved rock structure.

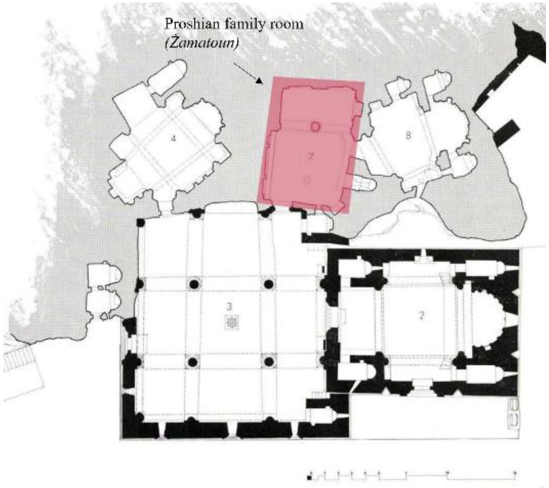

Fig. 1. *First floor planimetry of Geghard Monastery, highlighted the Proshian familiy room (Žamatoun)(by Ara Stepanian, Telman Gevorgian, Edik Hovhannisian, Hratchia Gasparian & Edward Frangoulian, 1971)*

The main subject of this research is the conservation assessment of the Proshian family room (*Žamatoun*) in the Geghard Monastery, where most of the investigations were conducted (Fig.1). This choice is linked to the analyses that were already carried out in 2019 during the summer school organized by the National University of Architecture and Construction of Armenia (NUACA) and the willingness to compare the past situation with the current one. In 2019, indeed, a damage assessment of the western wall of the *Žamatoun* was carried out, resulting in a degradation map. The main stones present in Geghard were also identified during a summer school as tuff and basalt, both divisible into two different typologies according to their porosity values [6,7].

Materials and Methods

Measurements were done in situ using portable instruments, allowing us to know the Proshian family room's conservation state. Considering specially built heritage, micro-analyses on some specific point may not be representative. In this sense, portable instruments play an important role in a better understanding of the object as a whole [8]. Moreover, these surveys are of great importance in the selection of micro-samples for further laboratory analyses [9].

Environmental monitoring

Knowledge of the environmental condition is essential to assess the influence of possible fluctuations in humidity and temperature on the stability of materials [10]. The environmental conditions were monitored with a data logger *EasyLog EL-USB-2-LCD*, which allows the measurement of air humidity and temperature from 25/04/2023 until 02/06/2023. Generally, the T and RH% monitoring requires at least one year of measurements. Due to organisational needs, we decided to collect these parameters during the season transition from spring to summer. The instrument was located at a height of ± 3 m on the architrave of the entrance of the analysed room. Temperature and humidity were measured every 30 minutes.

Visual survey: degradation maps

Once a research and conservation campaign on cultural heritage monuments has been planned, a visual survey is the first step to pursue. These surveys are essential to have a clearer understanding of the state of conservation of the monument and the main degradation phenomena with their extension and possible causes.

These evaluations should always be paired with photographic documentation, which was done also in the Geghard complex in 2018, paying more attention to the Proshian family room, where also degradation maps of the different sections of the space were constructed following the ICOMOS glossary guidelines[1].

The degradation maps were made using the *AutoCAD* drawings shared by architect Nanar Kalantarian and subsequently modified according to the needs and the *GIMP-Image manipulation program* to highlight the different degradation patterns. These maps are fundamental to having an immediate view of the situation, and they must be understandable by everyone to be a base for future interventions and analyses. To complete this survey, microscopic pictures were also taken in visible and UV light with a Dino-Lite portable microscope (magnification: 51,3x; unit: mm).

[1] ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns, 2008.

Water absorption measurement: sponge-test method

The sponge method[2] is a valid, non-invasive way to measure the initial rate of water absorption of the materials. The amount of water absorbed is in relation to the physical characteristics of the materials and their state of conservation. In addition, it gives crucial information on future conservative interventions with protectives and consolidants [11].

In the case under analysis, around 240 points were analysed, always using the same kind of sponge (contact area = 110 cm^2) with the same initial quantity of water; the contact time between sponge and stone surface was 30 seconds, following the normative UNI Normal 11432-2011[3]. The distance from one measurement to another was ± 40/50 cm, and they reached a maximum height of 180 cm. To better visualise the results, we reported the water absorption at the different points as g/m^2 directly on the images also used for the degradation maps.

Ultrasonic analyses

The ultrasonic investigation is a non-destructive method to study the internal structure of a material without affecting it. This method relies on analysing the wave velocity that crosses the selected object, enabling the assessment of intrinsic material properties, including homogeneity, and the presence of fractures or cavities. The results are based on the "travel time" or "time of flight" of the generated acoustic waves that cross the sample. Altered and weakened zones of the structures, along with the occurrence of microfractures and material flaking, can be spotted by lower acoustic velocity values than in unaltered materials [12].

Knowing the distances between the source (usually a piezoelectric transmitter that emits a frequency higher than 20 kHz) and receiver it is possible to calculate the wave velocity inside the material (1). Usually, the time of flight of the analysed material is compared with its healthy counterpart or a reference standard [13].

Wave velocity formula:

$$V = \frac{L}{t - t_0}, \quad (1)$$

V = ultrasonic wave velocity, L = measuring length, t = measured time, t_0 = time correction value.

Based on data collected at different points, it is feasible to compute tomographic maps. These representations offer a visual depiction of the internal condition of the structure or object under analysis, with distinct colours corresponding to varying travel times.

In the case under analysis, it was used the *All-in One SYSTEM (SolGeo Instrument)* in 4 different areas of the Proshian family room walls and on the big basaltic octagonal column. To overcome possible problems with the stone's high level of sensitivity, it has been decided to use the ultrasonic method with a piezoelectric transmitter with a frequency of 55 kHz. To reach more precise results, especially for the walls where it was not possible to measure significant distances, that can induce a signal's lack, the analyses were carried out in different coherent areas and then merged together. Figures 2a and b report the analysed wall areas and the corresponding paths. Except from *area (1)* all the analysed walls were measured more than once with the same matrix of points as it is possible to understand from the images. Figure 2c shows the multi-path in the octagonal column.

Results and Discussion

Environmental monitoring

From the environmental monitoring results (Fig.3), it is possible to observe how, from 25/04/2023 until 02/06/2023, the temperature swings between a minimum of 9 °C and a maximum of 17.5 °C and the relative humidity values go from a minimum of 55% to 83%. These values are coherent with what was expected since

[2] UNI Normal 11432-2011, Beni culturali, Materiali lapidei naturali ed artificiali - Misura della capacità di assorbimento di acqua mediante spugna di contatto.

[3] Ibid.

the analysed room is carved into the rock, and inside the monastery, there is no heating system [10]. For these reasons, the oscillations in the Proshian family room could be associated with the number of tourists inside the room and the external weather conditions.

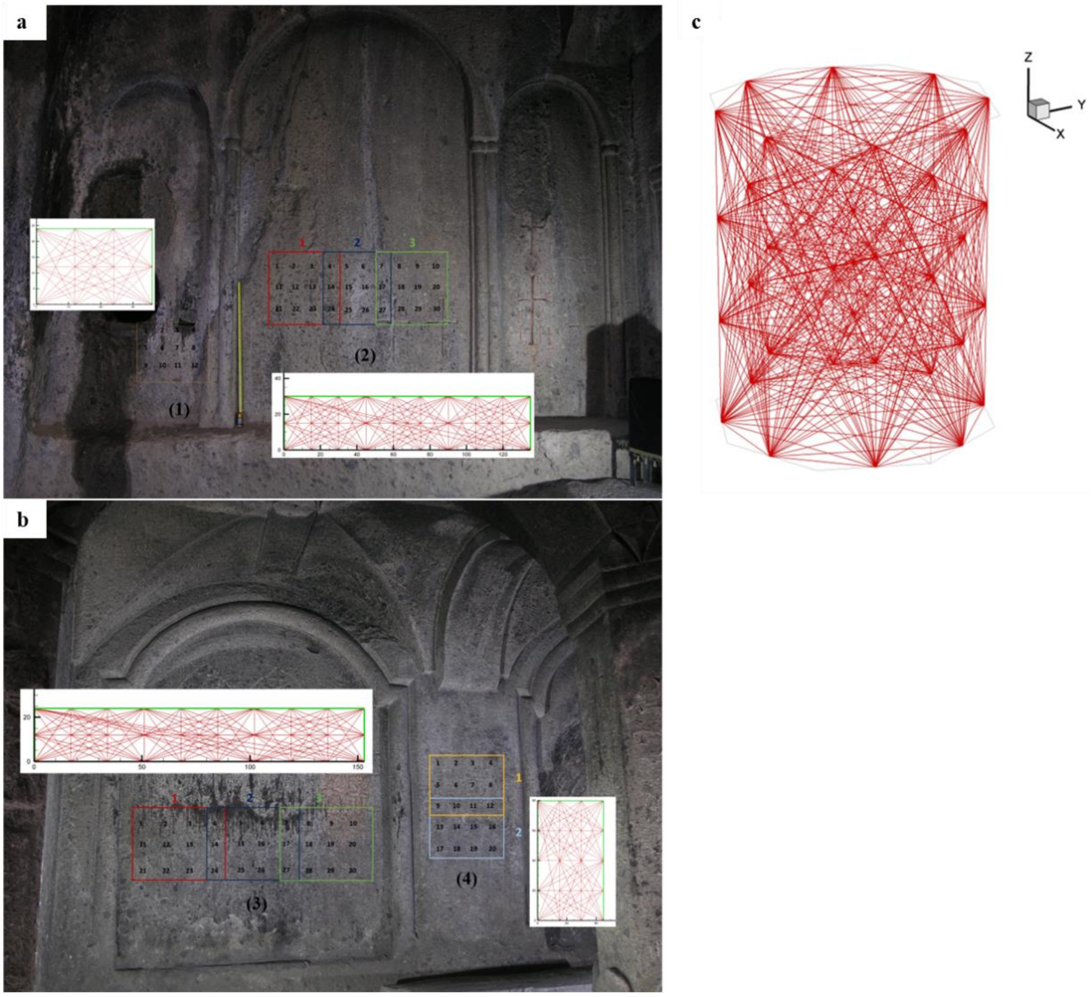

Fig. 2. *Ultrasonic paths used for the analyses. a & b) Points where the ultrasonic analyses were carried out on area (1), (2), (3) and (4) with the correspondent analysed paths; c) Resulting column paths*

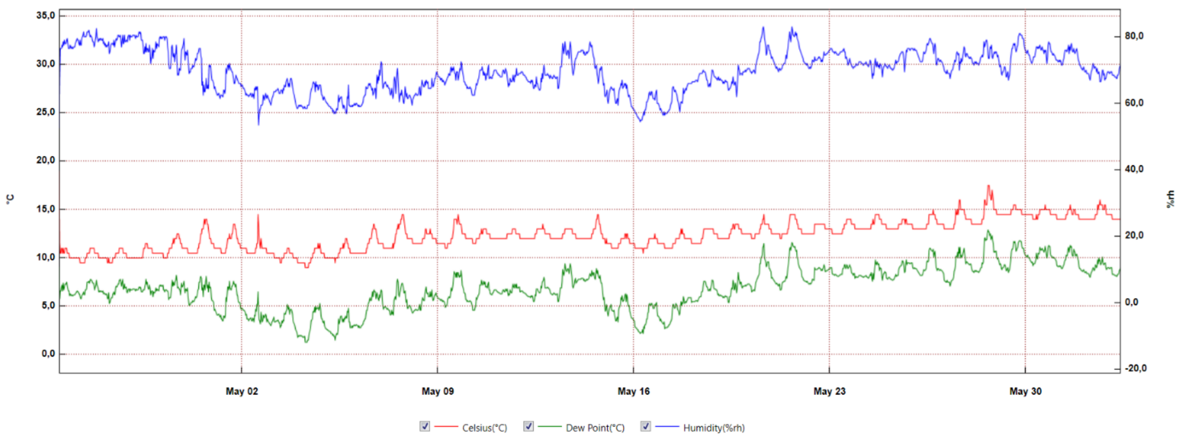

Fig. 3. *Environmental monitoring results from 25/04/2023 to 02/06/2023*

Even the dew point behaviour could correspond to the possible number of visitors as it increases at the busiest visiting hours. Crowded rooms are known to have more moisture content due to people's breathing [14]. Despite that, the water vapour condensation is never reached. Moreover, the temperature is slightly increasing over the months, which would be consistent with the external weather conditions of that period. We can also notice that higher temperatures usually mean higher RH values.

Visual survey: degradation maps

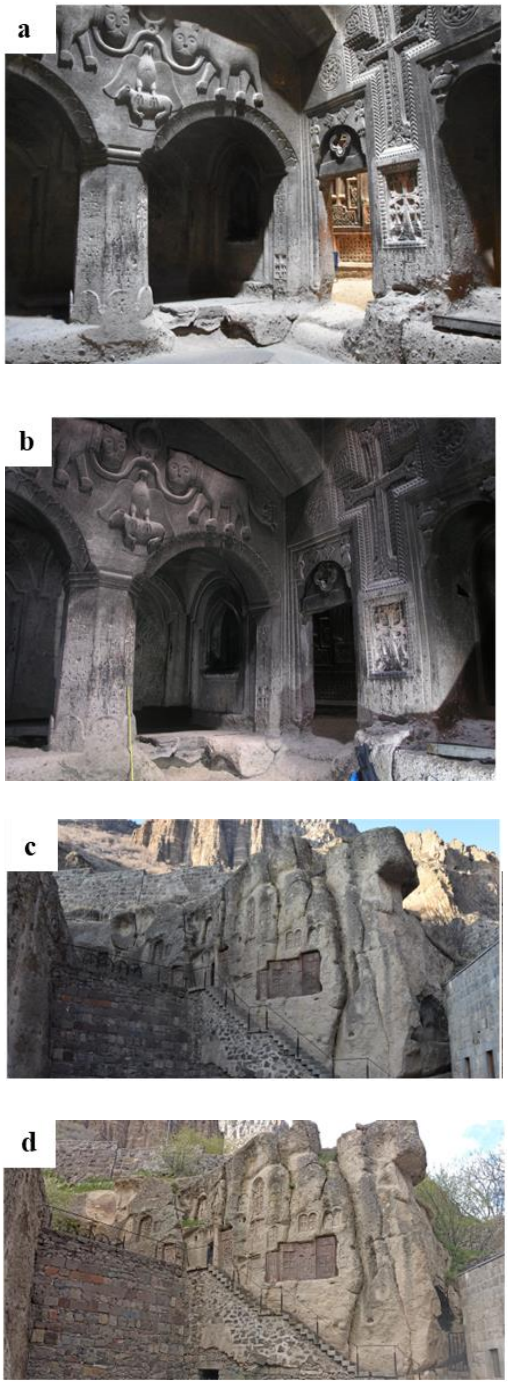

Fig. 4. *2018 and 2023 picture comparison: on the left-side, pictures corresponding to 2018, on the right-side pictures corresponding to 2023; a & b - Detail of the Proshian family room, c & d - Detail of the outside*

Thanks to the comparison of 2018 pictures, it is generally possible to notice that in the monastic complex we cannot observe important differences over 5 years, as shown in Figures 4a and b. However, some exceptions are present, such as in the case represented in Figures 4c and d, where a piece of rock above the stairs fell during the considered time span.

The degradation maps depicting the vertical surfaces of the analysed room are presented in Figure 6. A comprehensive legend is provided in Figure 5 illustrating various patterns along with brief descriptions[4], their corresponding definition and representative images, all arranged alphabetically.

To promptly understand the situation, a less detailed legend is reported on each map where it was decided to emphasize the most evident degradation processes.

In general, scaling is evident on all walls alongside a white encrustation, probably due to salt crystallization and wax deposits. Additionally, it is possible to observe, especially on the sculpted sections, that the lower zones exhibit a considerably more critical condition than the higher zones.

Water absorption measurement: sponge-test method

Figure 7 shows the graphical representations of the water absorption measured in the different areas of the Proshian family room. Each of these visual representations is subsequently linked to quantitative values expressed in g/m^2 *sec*, following the UNI Normal 11432-2011[5]. The scales used in the colour maps report their maximum and minimum value according to each zone and the values are reported in grams.

The colour maps in Figure 7a depict the western wall of the analysed room, showcasing a distinct alignment of the results with the wall's morphological features and degradation patterns. This is particularly evident on the right side of the drawing, specifically at the single arch. A comparison of these values with the degradation map of the corresponding area reveals a possible correlation between the two datasets. Water absorption, for instance, is 19.64 g/m^2 *sec* in the eroded area and 6.06 g/m^2 *sec* in the closest better-preserved area. The relationship between degradation patterns and water intake is observable in all the analysed areas.

Throughout these findings, a recurring pattern emerges, particularly in areas exhibiting greater deterioration, where water absorption appears to increase, as seen in the scaling regions. An opposite behaviour is observable in those areas characterized by a thick layer of wax deposit, as expected.

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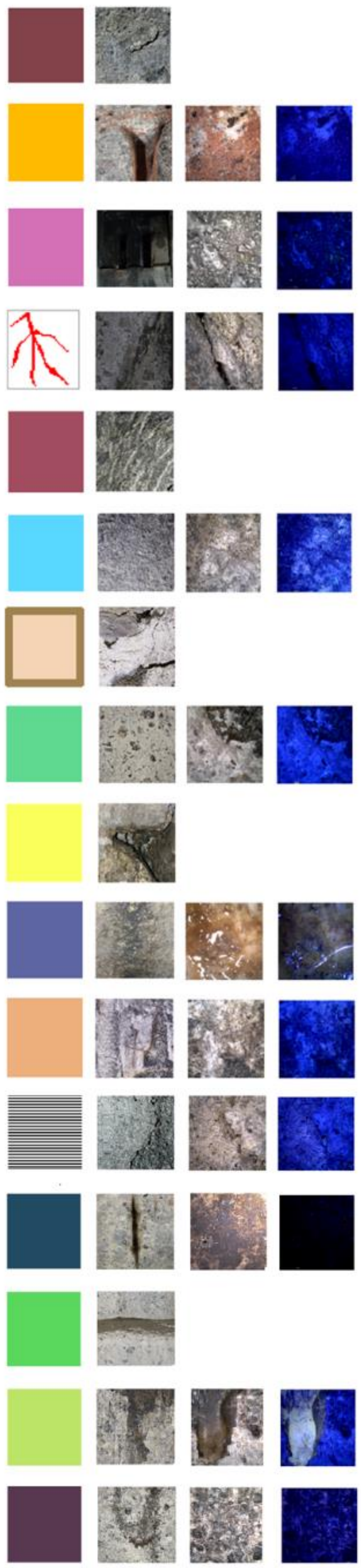
[4] ICOMOS-ISCS: Illustrated glossary on stone deterioration patterns, 2008.

[5] UNI Normal 11432-2011, Beni culturali, Materiali lapidei naturali ed artificiali - Misura della capacità di assorbimento di acqua mediante spugna di contatto.

Macro-picture | Micro-picture VIS | UV



Degradation pattern's name	ICOMOS definition	Annotations
Blistering	Separated, air-filled, raised hemispherical elevations on the face of stone resulting from the detachment of an outer stone layer. This detachment is not related to the stone structure.	
Chalk Graffiti	Engraving, scratching, cutting or application of paint, ink or similar matter on the stone surface.	Here it was deliberately specified «chalk» to distinguish these graffitis from those made with wax.
Colouration	Change in hue, value and/or a gain in chroma.	
Crack	Individual fissure, clearly visible by the naked eye, resulting from separation of one part from another.	
Cut	Loss of material due to the action of an edge tool. It can have the appearance of an excavated cavity, an incision, a missing edge, etc…	
Erosion	Loss of original surface, leading to smoothed shapes.	This term was used to distinguish whenever there were other and more intensive mechanical damages related to mechanical loss.
Improper intervention	Intervention with the aim of restoring the concerned object, which, however, is not appropriate. It may be due to the application of inappropriate materials (colour and texture clearly different from the original material)	TERM NOT PRESENT IN THE ICOMOS GLOSSARY
Loss of Matrix	Partial or selective elimination of the stone matrix, resulting in protruding compact stone components.	
Missing part	Empty space, obviously located in the place of some formerly existing stone part.	
Moisture area	Corresponds to the darkening (lower hue) of a surface due to dampness.	This term was used as a general term for those surfaces where the water presence is evident. Thus also for areas that were actually wet.
Salt encrustation	Compact, hard, mineral outer layer adhering to the stone. Surface morphology and colour are usually different from those of the stone.	«Salt» was deliberately specified to highlight the presence of an adherent natural white material
Scaling	Detachment of stone as a scale or a stack of scales, not following any stone structure and detaching like fish scales or parallel to the stone surface. The thickness of a scale is generally of millimetric to centimetric scale.	
Staining	Kind of discolouration of limited extent and generally of unattractive appearance.	
Rounding	Preferential erosion of originally angular stone edges leading to a distinctly rounded profile. Rounding can especially be observed on stones which preferably deteriorate through granular disintegration	
Wax deposit	Accumulation of exogenic material of variable thickness.	The term «wax» is used to specifically indicate that this kind of deposit is often a thick adherent layer and nothing like a dust deposit for instance.
Wax graffiti	Engraving, scratching, cutting or application of paint, ink or similar matter on the stone surface.	Here it was deliberately specified «wax» to distinguish these graffitis from those made with a chalky material.

Fig. 5. *General legend used for the identification of the degradation patterns highlighted in the degradation maps*

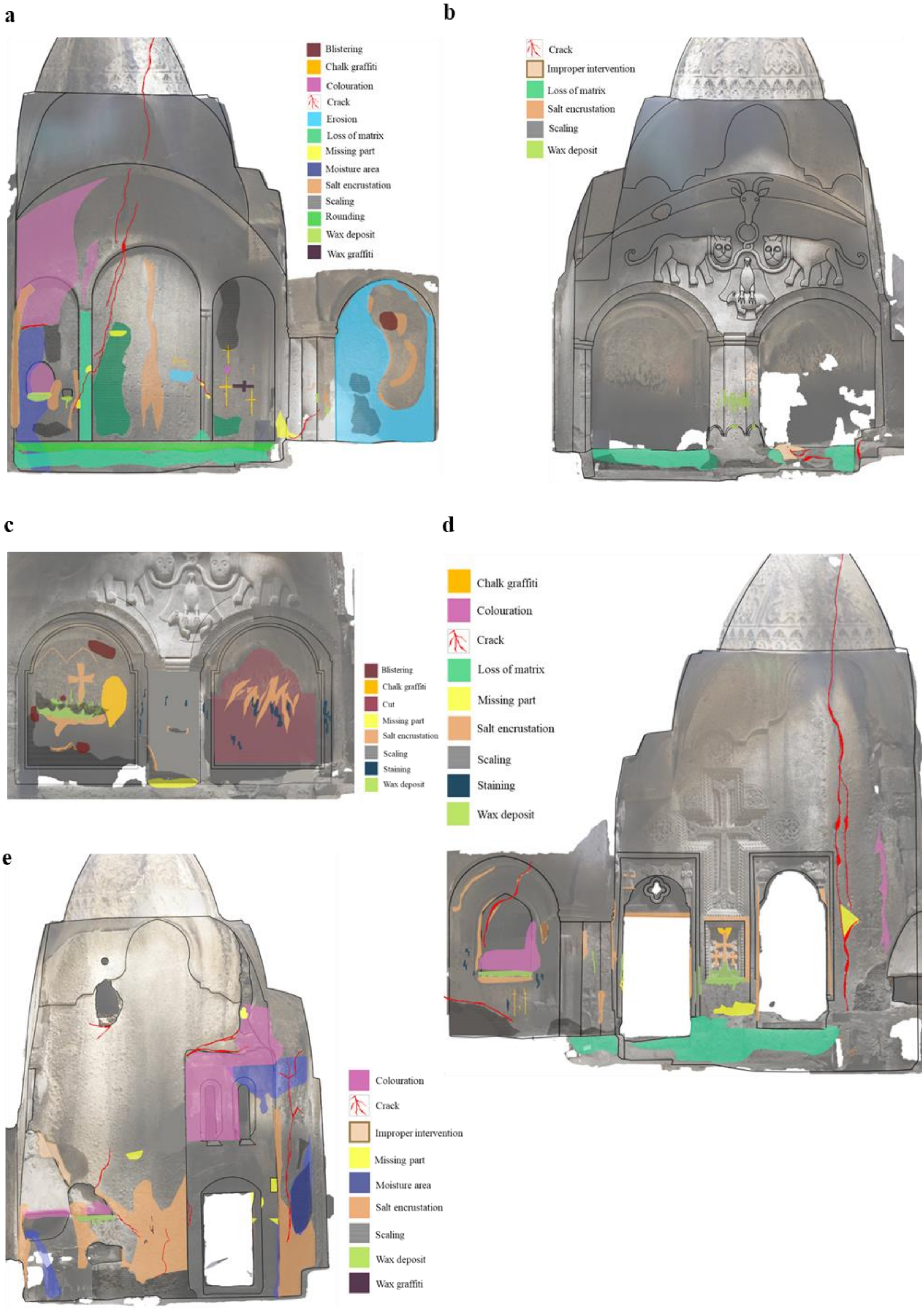


Fig. 6. *Resulting degradation maps of the Proshian family room: a - Western wall, b - Octagonal column (view from the centre of the chamber), c - Northern wall, d - Eastern wall, e - Southern wall*

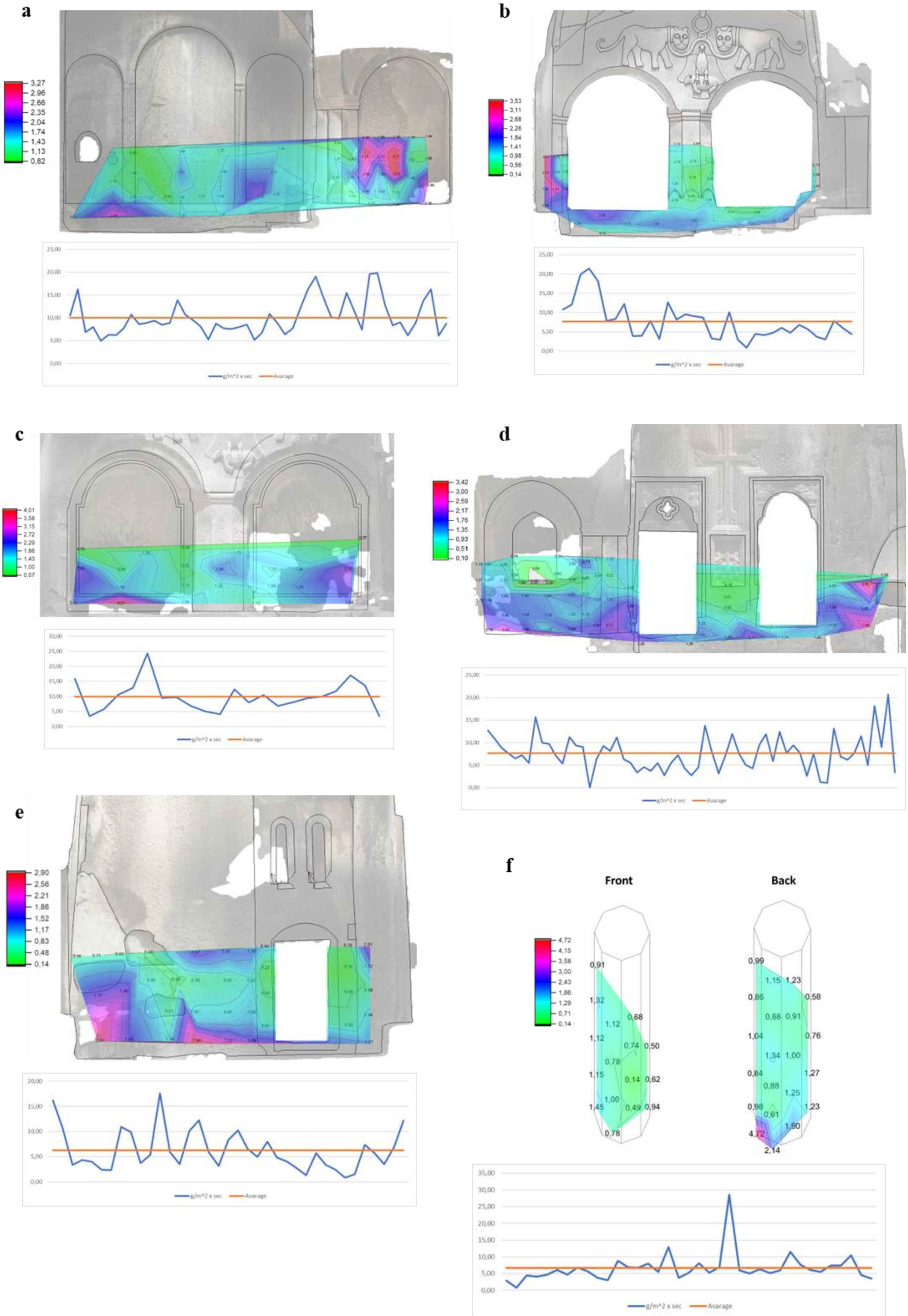


Fig. 7. *Sponge-test results: a - Western wall, b - Columns and base (view from the centre of the chambre), c - Northern wall, d - Eastern wall, e - Southern wall, f - Octagonal column*

Ultrasonic analysis

The tomographic maps are accompanied by a reference scale of the time of flight, which on the wall surfaces ranges from 1000 to 3000 m/s, while on the column it spans from 1500 to 5000 m/s (Fig. 8). The survey results of the wall surfaces were also associated with the corresponding image (representative of the area) to better comprehend their localization.

Figure 8a showcases the areas we analysed on the western wall of the Proshian family room. Notably, we observe lower values (represented in black) concentrated primarily along the border of the central arch (*area (2)*). Conversely, higher values are evident in area *1*. These findings align with the surface conditions: differential erosion on the left side of the large arch and the presence of engraved crosses on the right side. The stone between these two points exhibits lower velocity values, indicating a healthier and more compact condition.

Area (4) predominantly reflects a compact and relatively healthy condition (Fig. 8b). However, there is a spot in the middle with slightly higher values, corresponding to an area with scaling. In contrast, *area (3)* displays higher values, which, confronted with the degradation map of the northern wall, match the degradation patterns such as scaling as well as blistering on the left side.

The column results are reported in Figure 8c where, as previously mentioned, the scale is much higher than for the other analysed areas. This feature highlights the compactness of this architectural element reflecting what is observable to the naked eye. Anyway, Figure 8c displays different sections of the measurements where some lower values can be noticed on one edge on the upper side of the column.

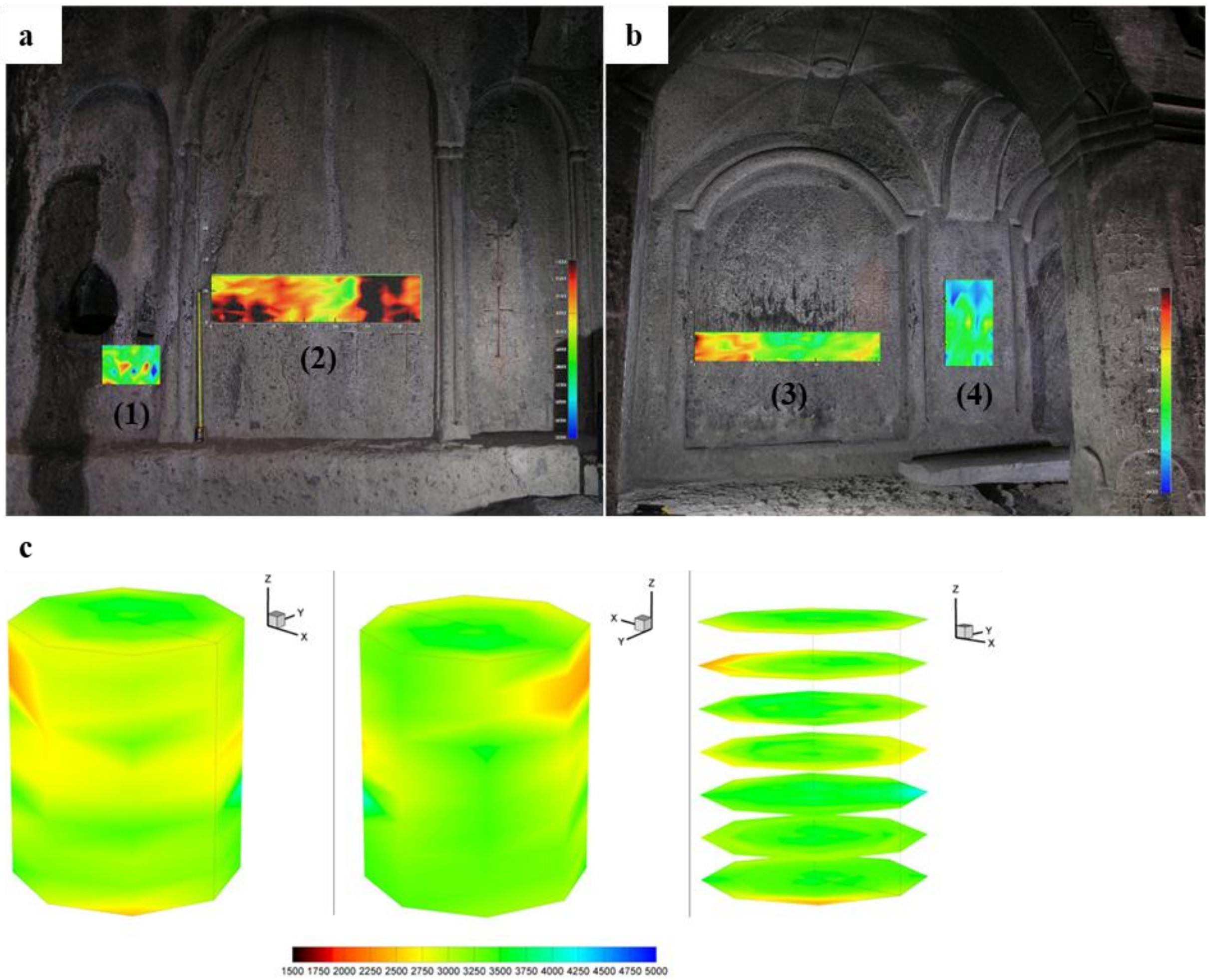


Fig. 8. *Tomographic results: a - Western wall area (1) and (2), b - Northern wall area (3) and (4), c - Octagonal column*

Conclusion

In conclusion, this work thesis aimed to give guidelines for future interventions in the Geghard Monastery that could also be applied in other Armenian realities and other secluded heritages with similar situations. Specifically, the in situ investigations are user-friendly thanks to their easy application. However, a digital transposition of the results associated with colour maps is truly important since it can give an immediate and straightforward understanding of the studied circumstances.

The non-invasive in situ analyses also gave essential indications of the state of conservation of the monastery, primarily of the room analyzed. The first step was the visual survey with the development of degradation maps, which allowed us to quickly realize the localization and main ongoing degradation phenomena. It was also helpful for the comparison of the other non-invasive analyses. The comparison of the conservative situation related to the examined area status over five years, thanks to the use of 2018 pictures, reports a relative structure stability that requires, in any case, urgent conservative interventions.

Acknowledgements

The authors gratefully acknowledge the support given by Dr Ing. Daniele Spizzichino (ISPRA).

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