

WEATHERING PROCESSES AND THEIR EFFECTS ON STONE-BUILT CULTURAL HERITAGE. CASE STUDY: "SAINT ARCHANGELS" CHURCH, DEAG VILLAGE

MONICA ILIEȘ¹, I.A. IRIMUȘ¹, MĂDĂLINA RUS¹

ABSTRACT. – **Weathering Processes and Their Effects on Stone-Built Cultural Heritage. Case Study: "Saint Archangels" Church, Deag Village.** Rural churches are an essential part of the Romanian cultural and historic heritage. Unfortunately their preservation is endangered by a number of factors, both natural (weathering) and anthropogenic (human neglect). Due to the complex nature of the conservation and restoration treatments, an interdisciplinary approach is therefore required. This study focuses on the damage diagnosis methodology applied on the lithic component of the "Holy Archangels Michael and Gabriel" Church in Deag village. The methodology consists of a series of investigations carried out both *in situ* (macroscopic analysis) and in the laboratory (microscopic analysis) which will provide reliable data concerning the weathering processes and their effects. The results will serve in the future elaboration and implementation of conservation and restoration treatments.

Keywords: *cultural heritage, weathering, lithic component, damage diagnosis, investigations*

1. INTRODUCTION

The preservation of our cultural heritage is constantly endangered by the inevitable action of weathering processes. Although stone is one of the most durable building materials, in the course of time, it can be severely damaged by physical, chemical or biological weathering forms. Accurate damage diagnosis is required in order to ensure the monument's structural and aesthetic integrity. This can be accomplished by correctly identifying both the causes (weathering processes) and the effects (weathering forms or deteriorations).

2. MATERIALS AND METHODS

The methods chosen to carry out this study rely on *in situ* and laboratory investigations. The *in situ* investigation process involves the following three steps: identification of the lithotypes, identification and diagnosis of the weathering forms and sampling. A series of laboratory investigations are also performed on the collected samples.

¹ "Babeș-Bolyai" University, Faculty of Geography, 5-7 Clinicilor Street, Cluj-Napoca, Romania,
e-mails: moniilies@yahoo.com, irimus@geografie.ubbcluj.ro, rus_madalyna@yahoo.com

3. RESULTS AND DISCUSSIONS

The identification of lithotypes is based on macroscopic analysis. More detailed information concerning physical, chemical and mechanical properties can be obtained in the laboratory through microscopic analysis.

Identification and diagnosis of the weathering forms. The weathering forms are identified with the help of ICOMOS-ISCS “*Illustrated glossary on stone deterioration patterns*” and mapped according to their type, intensity and distribution using the mapping method developed by the Working Group “Natural stones and Weathering” from the Aachen University of Technology.

In situ sampling is necessary for further, more detailed laboratory analysis. The samples are collected from deteriorated stones, located in problematic areas, such as those in close contact with the ground or those exposed to weathering factors. Fresh rock samples are also collected from the original building rocks for comparative analysis.

The laboratory analyses of the samples can reveal detailed and accurate information about the damages that are not visible to the naked eye. It can also confirm or contradict the suppositions and theories formed during the *in situ* investigations (macroscopic investigations). *Optical microscopy and electron microscopy (SEM) analysis* offers detailed information about the visible and non-visible deteriorations, it can determine physical and mechanical properties of the material and its mineralogical structure. *The x-ray diffraction (XRD) method* is employed in order to determine the mineralogical composition as well as to identify new minerals, which have formed as a result of chemical weathering (e.g. salts).

Before carrying out the investigations, a profile of the monument must be made. This is usually done by acquiring information regarding monument identification, location, building techniques and materials, cultural importance, previous interventions and climatic conditions.

3.1. Case study: “Holy Archangels Michael and Gabriel Church”, Deag Village



Fig. 1. “Holy Archangels Michael and Gabriel Church”, South - East view.

3.1.1. Monument profile

The “Holy Archangels Michael and Gabriel” Church was built in the 18th century, in 1765. It is located in Deag, a small village situated in the Târnavé Hills, in Mureş County, 8 km away from its administrative town, Iernut.

The church was built, according to tradition, on a promontory. The walls were built with wooden beams arranged according to the blockbau system. The foundation is built with irregular blocks of stone, extracted from the nearby hills.

The study focuses on the damage diagnosis of the monument’s lithic component, the foundation. The stone-built foundation has suffered numerous degradations over time, caused by both environmental and human factors. In 2011 the foundation was damaged due to some superficial landslides. Consolidation works have been employed to strengthen the southern and eastern part of the foundation. The original eighteenth century stone was replaced by concrete slabs, an inadequate choice from an aesthetic and structural point of view.

The climatic conditions that characterise the Târnavé Hills favour the action of all weathering processes. The most probable to occur are the following types: frost weathering, wetting and drying weathering, salt crystallization weathering, chemical and biological weathering. Frost weathering (freeze – thaw) is justified by the negative temperatures recorded during winter, especially in January when the average temperature is -4°C and also by the sudden temperature fluctuations between positive and negative recorded in the seasons of transition (October, month of the first thaw and April, month of the last thaw). The mechanical weathering through wetting and drying can occur during the warm season, when summer rains are followed by periods of intense evaporation. The wetting and drying process is often accompanied by the salt crystallization process, thus causing more severe deterioration. The chemical and biological weathering are sustained by an average relative humidity of 76%-80% and by the high temperatures recorded in the summer season.

3.2. In situ investigations

3.2.1. Identification of lithotypes

Based on the macroscopic analysis and the acid chloride test, it has been found that the lithic material is carbonate cemented sandstone. This type of sedimentary rock is susceptible to weathering because of its high porosity and bedding planes that allow water to infiltrate (Tufescu, 1966).

3.2.2. Identification and diagnosis of the weathering forms

Delamination is predominant on the southern and northern parts of the foundation. The rocks with southern exposure are few in number but are severely affected (fig. 2). Some of the bedding planes completely detached and fell to the ground. The loss of lithic material has left a number of holes into the foundation (fig. 3). According to Torracca (2009), delamination is caused by the repeated action of freeze – thaw cycles (frost weathering). Aroldi (2005) attributes it to both frost weathering and termoclasty. The latter can be justified only in the case of the rocks that are situated on the southern side of the foundation which are exposed to direct solar radiation.



Fig. 2. Severe delamination along the bedding planes.



Fig. 3. Partial disintegration caused by severe delamination.

Some of the rocks located on the northern side of the foundation have been affected by both delamination and *granular disintegration*. The association of these two weathering forms has created a sculptural and sandy surface (fig. 4). White *efflorescence stains* have been noticed on a small number of rocks located at the lower part of the foundation. They are the result of the dissolution of the calcium carbonate and may indicate a more severe deterioration beneath the surface (fig. 5). Oxidation has affected a large number of rocks, on all sides of the foundation, causing chromatic modification but did not involve any visible surface deterioration.



Fig. 4. Delamination and granular disintegration.



Fig. 5. White efflorescence caused by the dissolution of calcium carbonate.

A form of biological weathering, algal colonisation, has been identified on the western side of the foundation but its extent is limited to two stones that are in direct contact with the ground. A further microscopic analysis will reveal more accurate information about the extent of the biological weathering.

The *in situ* macroscopic investigation was finalised with the mapping of the weathering forms, a method intended for monitoring their evolution (fig. 6 and 7). The middle section of the northern side was chosen for this purpose because it includes all identified weathering forms.

WEATHERING PROCESSES AND THEIR EFFECTS ON STONE-BUILT CULTURAL HERITAGE
CASE STUDY: SAINT ARCHANGELS CHURCH, DEAG VILLAGE

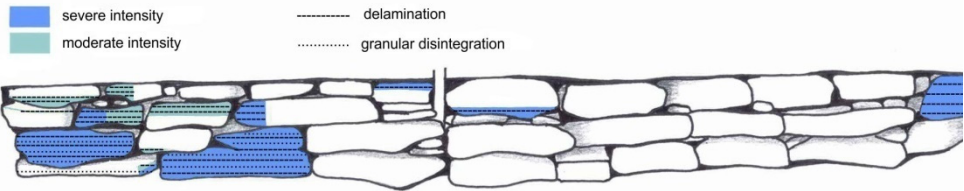


Fig. 6. Physical weathering forms.

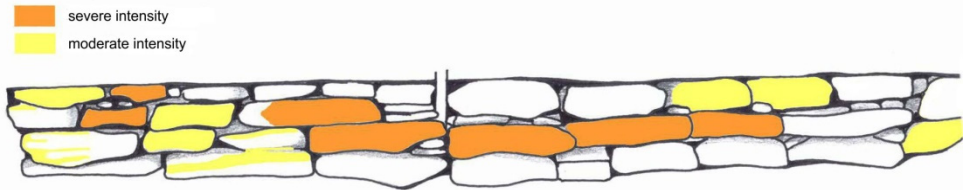


Fig. 7. Chromatic alteration caused oxidation.

3.2.3. Sampling

The samples were collected from the southern and northern sides of the foundation, from severely damaged rocks, that allowed easy detachment of the lithic material. Fresh rock samples were also taken from the source area which is located in close proximity to the monument. This area was once used by the local population to extract building materials but, in the 20th century, it was repurposed for agricultural needs. The samples were collected from a stone block that was taken out of the ground during ploughing.

3.3. Laboratory investigations. Optical microscopy

3.3.1. Petrography analysis

Thin sections of the samples were analysed using a Zeiss Axiolab Microscope. The following structural components were identified: mica, feldspar, quartz and bioclast fragments, cemented together with calcium carbonate (fig. 8 and 9).

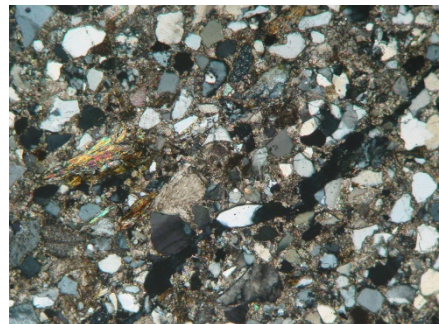
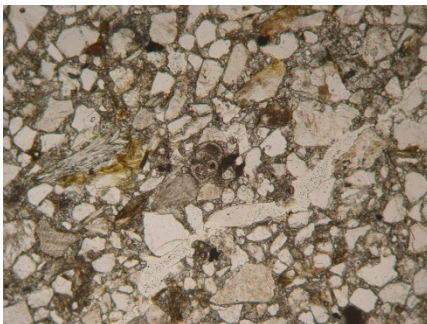


Fig. 8. Microscope analysis in plane – polarized light. Fig. 9. Microscope analysis in crossed – polarized light. Both photos show: mica, quartz and bioclast fragments.

3.3.2. Weathering forms

The microscope analysis of the samples has identified the presence of secondary gypsum crystals (*subefflorescence*) (fig. 10 and 11). The pressure exerted by the newly formed crystals is rather dangerous as it may cause structural damage by breaking down the walls of the pores. The *dissolution of calcium carbonate* has left empty spaces between the particles (dissolution pores), thus weakening the sandstone's mechanical resistance and facilitating further weathering (fig. 10 and 11). The lack of cement is one of the causes of granular disintegration. *Oxidation* was caused by both chemical and biological weathering. Microscope images show the presence of iron bacteria (fig. 12 and 13).

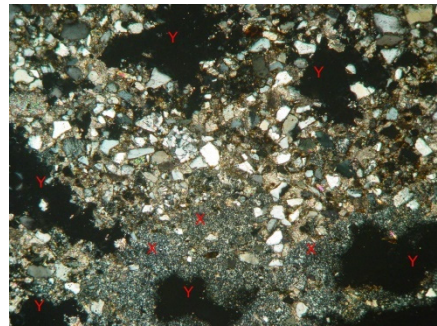
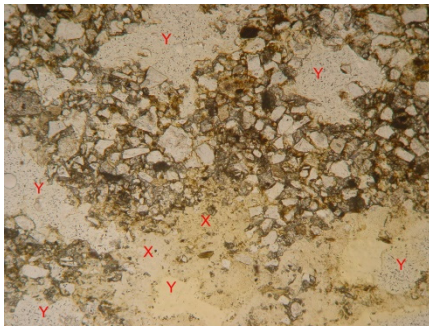


Fig. 10. Microscope analysis in plane - polarized light. **Fig. 11.** Microscope analysis in crossed - polarized light. Both photos show: X - gypsum crystals; Y - dissolution pores.

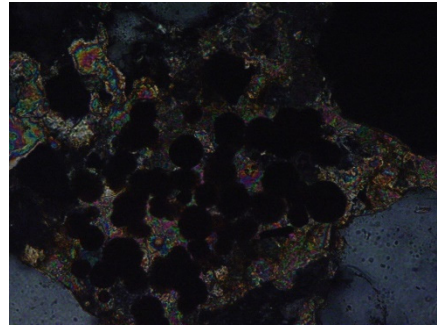
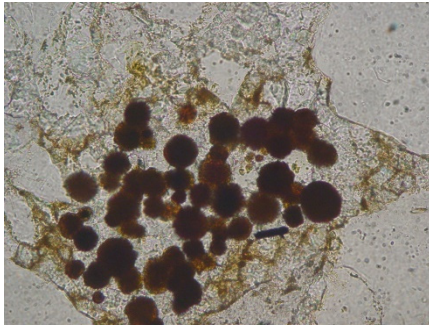


Fig. 12. Microscope analysis in plane - polarized light. **Fig. 13.** Microscope analysis in crossed - polarized light. Both photos show iron bacteria.

4. CONCLUSIONS

The preliminary results show that the lithic material has been damaged by all three weathering processes (physical, chemical and biological ones). The complexity of the weathering forms calls for further laboratory investigations such as scanning electron microscopy (SEM) and X-ray diffraction (XRD). The study is part of a wider

research project that seeks to provide reliable damage diagnosis for the elaboration and implementation of conservation and restoration treatments for the “Holy Archangels Michael and Gabriel” Church. The methodology can also be applied to other similar stone-based monuments.

ACKNOWLEDGEMENTS

This work was possible due to the financial support of the Sectorial Operational Program for Human Resources Development 2007-2013, co-financed by the European Social Fund, under the project number POSDRU/159/1.5/S/132400 with the title „Young successful researchers – professional development in an international and interdisciplinary environment”.

REFERENCES

1. Aroldi, C. (2005), *Introducere in petrologia sedimentară*, Edit. Accent, Cluj-Napoca
2. Fitzner, B. and K. Heinrichs, (2002), *Damage diagnosis on stone monuments: Weathering Forms, damage categories and damage indices*. In R. Přikryl and H. A. Viles (ed.), *Understanding and Managing of stone Decay (SWAPNET 2001)*, Prague: Charles University, The Karolinum Press.
3. ICOMOS (International Council on Monuments and Sites) and SCIS (International Scientific Committee for Stone) (2008), *Illustrated Glossary on Stone Deterioration Patterns – Glossaire illustré sur les forms d’altération de la pierre*, Edit. Monuments and Sites, Paris.
4. Ollier, C. (1969), *Weathering*, Oliver and Boyd, Edinburgh.
5. Torracca, G. (2009), *Lectures on Materials Science for Architectural Conservation*, The Getty Conservation Institute, Los Angeles.
6. Tufescu V. (1966), *Modelarea naturală a reliefului și eroziunea accentuată*, Edit. Academiei Republicii Populare Române, București.

