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Petroarchaeometrical Study of the Lithic Material Used to Build the Cârța Cistercian Monastery, Sibiu County

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Introduction

A great part of the historical and cultural heritage consists of stone built monuments. In Romania, many of these monuments are in an advanced state of decay. Different studies are needed to properly assess the weathering processes and to propose sustainable solutions for conservation, in order to avoid the irretrievable loss of cultural heritage.

The main purpose of this study is to characterize the lithic material used in construction of the Cârţa Cistercian Monastery, to identify weathering forms occurring from the action of various external factors and to estimate the lithic material capacity to resist a possible restoration project of the monument, as a first step in a coherent initiative of monument conservation.

The choice of Cârţa monument for this study is motivated by its historical importance, its architectural value, but also by the advanced state of degradation of the walls.

The study of the materials used in construction with heritage value requires the use of less invasive methods. In the case of Cârţa monument, we used several specific methods for measuring and mapping, paying attention to identify macroscopic weathering processes, in order to limit the aggression on the building to minimum.

The results of the mappings and direct observations on the state of the lithic material allowed decisions concerning sampling methods, materials used and types of laboratory tests needed to determine the petrography and mineralogical composition, the weathering forms and their causes, and also determining the provenance of the lithic material.

We will present in the following chapters some specific weathering processes of the lithic material. It was also studied how the geographical orientation of the building is affecting the development of typical weathering processes due to exposure to insolation, moisture and wind erosion, but also the properties inherited from the depositional environment (petrography and mineralogical composition, grain size, porosity, etc.).

Some final restoration and preservation methods that could be used for the edifice from Cârţa were discussed in the end. Both traditional and less expensive methods, as well as some modern techniques were presented Even if the decision regarding the best choice for restoration and conservation is not ours, we hope that this study is a starting point to save what remains of Cârţa Cistercian monastery.

1. Cârţa Cistercian Monastery

1.1 History of the monument

The particular architectural style of the building from Cârţa is associated to the Cistercian order of Catholic monks. Cârţa Monastery was located in the western half of Făgăraş County. Stonemasons workshops from that time were messengers and pioneers of the gothic style in Transylvania (Busuioc-von Hasselbach, 2000).

The monastery was founded during the reign of King Andrew II of Hungary at the beginning of the thirteenth century and was abolished in 1474 by King Matthias Corvinus.

Dimensional stones were used at the building only for architectural details, the monastery walls being otherwise made out of crushed stone or river rock.

The study focuses on the main portal of the west façade and the geminate window of the former chapter hall. It is assumed that they were built in different stages.

The main building of the monastery (former nave of the church) is 60 m in length on east-west direction, the transept is 30 m wide and its height is approximately 25 m. The total length of the architectural complex is over 80 m in north-south direction.

1.2 Restoration and conservation work, prior to the study

Although along history important events have caused severe damages to the building, only a few restoration attempts have occurred over the years.

The most important and major restoration in the last two centuries took place between the years 1913 to 1914. The rock used then is volcanic tuff. In the 1960s and 1980s, they used concrete to fill some gaps and fractures, a material unsuitable for a restoration, which has led in some cases to the progress of deterioration.

2. Theoretical aspects

In order to properly prepare the study, some theoretical aspects were necessary, in order to clarify the working principles and the context in which the exemplified processes occurred in this case study.

2.1. <u>Sedimentary rocks - Sandstones</u>

Sedimentary rocks are most commonly used on the studied location. For arenaceous cohesive rocks we used the classification proposed by Folk in 1968.

2.2. <u>Weathering processes on building stones</u>

Rock weathering is the result of a wide range of processes that may act separately or simultaneously. It is therefore necessary to focus on the study of connections between processes, weathering forms, rock properties and specific environmental conditions (Turkington & Paradise, 2005).

The classification developed by Fitzner and internationally acknowledged, was used as basis for mapping of weathering on monuments facades. The classification system was founded by Fitzner et al. (1992) and subsequently shown Fitzner and Heinrichs (1994).

2.2.1. Parameters responsible for stone decay

Rocks used as building material are suffering different physical or chemical degradations, under the influence of various factors, causing changes in color, texture, strength, chemical composition and other properties of the original material.

Most crystals contained in the rocks have properties that can vary with different crystal directions, such as their expansion along the crystallographic directions when temperature is increased. Following this process, the rocks are affected more at the surface of the material, rather than deeply (Koch et al., 2008).

The most effective weathering processes at the surface of the rocks start with the freezing of the water from the pores of the material, the pressure resulting from ice crystallization processes leading to weakening the rock structure (Koch et al., 2008). A similar weathering process may occur due to crystallization pressure that occurs in the formation of salts (Hosono et al., 2006).

Acidic or basic chemical reactions can sometimes lead to cement and clasts dissolution within the rock. These processes affect especially soluble carbonate minerals (Winkler, 1966, Koch et al., 2008).

Anthropogenic activity increases pollutants concentrations in the atmosphere (Price, 1996). Rock weathering in urban areas is much higher than in rural areas because urban atmosphere is enriched with CO_2 and sulphates, resulted mainly from burning of the fossil fuels.

Among the factors that degrade the rocks microorganisms and plants that live on or inside the rock are also included.

2.2.2. Frequent weathering on sandstones

Studies on rock weathering tend to become more reductionist by the use of microscopy to examine the processes to micro and nano scale (Turkington & Paradise, 2005). Studies on sandstones affected by pollution in urban areas include examples of black crusts on buildings (North & Tronner, 1995) exposed sandstone weathering (Halsey et. Al, 1995) and loss of stone material due to the effect of salts on the facade (Turkington & Smith , 2000). There is still a dispute whether these deposits and crusts may act as a protective layer or whether they function as a reservoir for potential destructive salts which can then migrate below the surface of rocks (McAlister, 2006).

Moisture transport in sedimentary rocks is mainly due to capillary forces, thus soluble cations can be transported inside the rock and determine the formation of crust at the surface (Koch & Sobott, 2008, Koch et al., 2008; Răcătăianu, 2010).

Lately, the interest on the nature of rocks bio-weathering and the role of biological material eroding the surface has increased. Some researchers (Lee & Prason, 1999) have suggested a more protective than destructive role to elliptical lichens on certain types of rocks, but generally it is considered that the microbial contamination contributes significantly to the weathering acceleration (Warscheid & Braams, 2000).

2.3. <u>Geological context</u>

2.3.1. Transylvanian basin

Transylvanian Basin is located inter-Carpathians bounded by Eastern and Southern Carpathians, and separated from the Apuseni Mountains by the Pannonian basin to the west and it is a major area of sedimentation.

The Cenozoic of Transylvania is related to the development of several successive sedimentary basins, which generated major sequences (Krézsek & Bally, 2006).

2.3.2. Geology of the southern part of Transylvanian Basin

Southern boundary of the Transylvanian Basin is represented by the northern edge of Făgăraş, Cibin and Sebeş Mountains, and consists of metamorphic rocks (Elias, 1955). The area located north of Făgăraş Mountains takes the form of a large erosion basin, Făgăraş basin, upper Pliocene – Quaternary age (Paucă et al., 1965).

The characteristic depositional environments for Sarmatian in southern Transylvanian Basin are: fluvial, fluvial, marginal marine (paralic), shallow-marine ramp (lower shoreface, inner and outer shelf) and deep-water palaeoenvironments (Silye, 2010).

Near Colun village we identified two outcrops, where Ilie (1955) described the Sarmatian as being well represented by sands, micaceous sandstones sometimes with concretion surfaces, and conglomerates, with small remains of molluscs and sandy clays.

2.4 <u>Influence of climatic factors</u>

All climatic factors interconnected (temperature, precipitation, winds) affects in time the weathering of the materials used in construction.

Temperature variations cause freeze-thaw cycles that have a high impact on the mechanical disaggregation of rocks as a result of expansion of water during freezing.

Rainfall conditions the volume of water that penetrates the pores and thus affects both the physical disintegration and salt dissolution that occurs.

Illustration and quantitative assessment of the various weathering forms can be detailed according to various materials, but also to the characteristics related to its exposure, like the location, geometry and orientation.

3. Methods

The following are the main methods of investigation used for the lithic material of historical buildings and how they can be applied for the site of Cârţa Cistercian monastery complex.

3.1 <u>Anamnesis</u>

Anamnesis was made after recommendations by Fitzner (2002) and it includes the identification of relevant issues related to the monument, its location, description in the context of art, its history and restorations or previous work.

3.2 <u>Outcrops investigations in determining the provenance area</u>

Samples of rocks unaffected by weathering must be taken from quarries known to be used for the building of the studied monument. In our case there was no mention of the exact location where the sandstone was taken from, only the mentioning of Colun village nearby the provenance area. After laboratory analysis, sandstone samples taken from these locations were compared with sandstone used at Cârţa.

3.3 <u>Sampling</u>

The samples taken from Cârța were small in size and few in number. They were collected from highly weathered blocks and from areas where the material was easily detached.

3.4 In situ measurements and investigations

It was necessary to obtain detailed diagnosis of the weathering forms, in order to characterize, interpret and evaluate the deterioration of the rocks.

3.4.1 Macroscopic investigations

The macroscopic investigations that we performed in situ on the lithic material refers to the types of rock used, description of the rock's color and differences in grain size with the naked eye or magnifying glass.

3.4.2 Monument mappings

For the mapping procedure we used detailed photos of the portal and the geminate window, which were used as background to perform mapping. To draw each block of stone Aiptek Media Tablet 14000U was used, after importing images in Corel Draw. It was then drew the outline of each block of stone, and they were then numbered according to their position.

3.4.2.1 Rock type mapping

Marked and numbered blocks were stained according to the type of building material used.

3.4.2.2 Clash test (sound velocity) mapping

Areas with different speeds of sound propagation through the material used for the building of the discussed parts (portal and geminate window), were represented in this mapping. We assigned different colors to differentiate the in situ measurements, these corresponding to the degree of weathering of the blocks.

3.4.2.3 Moisture mapping

This mapping is achieved after the measurement of moisture in the building material, with the device B. Gann Hydromette Compact Such data were then transposed on the simple mapping of the studied locations and processed using ArcGIS program into a map of the moisture from the surface material. They were then overlaid with the simple mapping of the blocks.

3.4.3 Determining the weathering forms

The complete table of the weathering forms classification, along with the definition of the corresponding parameters used to classify the intensities and the photo atlas of the weathering forms were presented by Fitzner et.al in 1995, and in 2002 Fitzner and Heinrichs have published an update of the classification of the weathering forms. The latter was used to identify the types of weathering present on the walls of Cârţa Cistercian monastery.

3.5 <u>Laboratory analysis</u>

3.5.1 Optical microscopy

After the manufacture of the thin sections, they were studied to a polarizing microscope Zeiss Axioskop and the microscopic images were taken with the compatible Progress Progress C10 correlated with Capture Pro 2.0 software.

Since the thin sections were made by impregnating samples before cutting and the most weathered parts (outside) were captured in sections, some of the weathering forms were easily identified on a microscopic scale.

3.5.2 Granulometry

The grain size analysis were performed were made on thin sections by measuring the diameter of over 300 clasts from each sample for the accuracy of the statistical data. We used the logarithmic phi scale, where $\Phi=-\log_2 d$ (d- clasts diameter). With it we represented graphically the cumulative curves of grain size frequency, which were subsequently used to calculate the average grain size (M) and the sorting coefficient (So) after Folk and Ward (1957).

3.5.3 Scanning electron microscopy (SEM)

The scanning electron microscope used to analyze the collected samples was TESCAN Vega 2 XMU, at Freidrich-Alexander University, Erlangen-Nuremberg.

3.5.4 X-Ray Difractometry

X-ray analysis is the classical procedure for determining the mineralogical composition and the most efficient method for identification of clay minerals and neoformation minerals incurred due to weathering, especially salts. X-ray diffraction studies were carried out on most of the sandstone samples, similar to the method described by Koch & Rothe (1979).

3.5.4.1 X-Ray analysis on powder sample

We performed the determining of the mineralogical composition of the sandstones on powder grinded samples. Equipment used was a Phillips PW 1310 diffractometer. Nickel-filtered Cu Kα radiation was used, and the generator was run at 35 kV and 25 mA. Scanning speed was 1^0 2 θ /min. By this method we could estimate the proportion of various minerals and the composition of the rock.

3.5.4.2 Clay mineral analysis

To prepare the samples for clay mineral analysis, the fraction finer than 2 μm was taken from suspension and placed on a glass plate, after removing $CaCO_3$. Clay minerals are frequently present in the fraction of sedimentary rocks and have an important role in their weathering. They are among the most susceptible to changes due to the presence of water.

3.5.5 Salt analysis

The salt analyses are considered semi-quantitative and they were made by chemical methods (Machery Nagel Photometer Nanocolor), in order to identify the content of nitrates and chlorides. Salt analyses are often proposed at restoration projects cause the methods involve a simple technique and very low costs.

3.5.6 $CaCO_3$ content

For the accurate determination of the total carbonate content, we used the “carbonate bomb” method (Müller & Gastner, 1971). Treatment of the sample with a solution of HCl in tightly closed container creates a CO_2 pressure proportional to the amount of $CaCO_3$ in the sample.

3.5.7 Porosity

Analyses were performed on samples taken from both parts of the studied sites: the walls from Cârţa and from the outcrops in the provenance area. We calculated using a mercury porosimeter the inter-particle porosity, intra-particle and the resulting total porosity.

3.5.8 Ultrasonic velocity tests

We calculated the speed of propagation of ultrasonic pulsation in two directions, where this was possible (a – parallel and b – perpendicular to bedding), to allow subsequent calculation of the anisotropy index (a / b).

4. Results of the analysis performed on the lithic material used at Cârţa Cistercian monastery

4.1. <u>Provenance area</u>

Mineralogical characteristics, petrography and paleontology of the sandstones that outcrop on Fermelor Valley/ Mare Valley, north-east of the village Colun, were compared with fragments of sandstone used in the abbey walls of Cârţa. The age of the deposits was confirmed by the sarmatian micropalaeontological associations identified in the clay deposits that intercalate the calcareous sandstone that outcrop at Scoreiu dam. Some foraminifera identified in thin sections, also confirms their middle Miocene age (Mihăilă et al., 2012).

The rocks used for the building of the monastery have the same mineralogical composition (including heavy minerals identified), the same micropaleontological association and similar gain size of clasts, as the ones collected from the outcrops of Colun.

4.2. <u>Noninvasive analysis</u>

We tried to obtain information as accurate and conclusive as possible by noninvasive methods of analysis, to avoid excessive sampling and thus affect the aesthetic aspect of the monument.

4.2.1. Rock type mapping

After macroscopic investigation we determined four different types of sandstone used to built the portal (Fig. 1) and the geminate window (Fig. 2) (Mihăilă & Benea, 2011).

Along with sandstones, which are the majority, we identified two blocks of limestone (type 5) that were used in the two friezes of the portal. Fragments of bricks were also used, probably at recent consolidation work, especially in the eastern part of the portal.

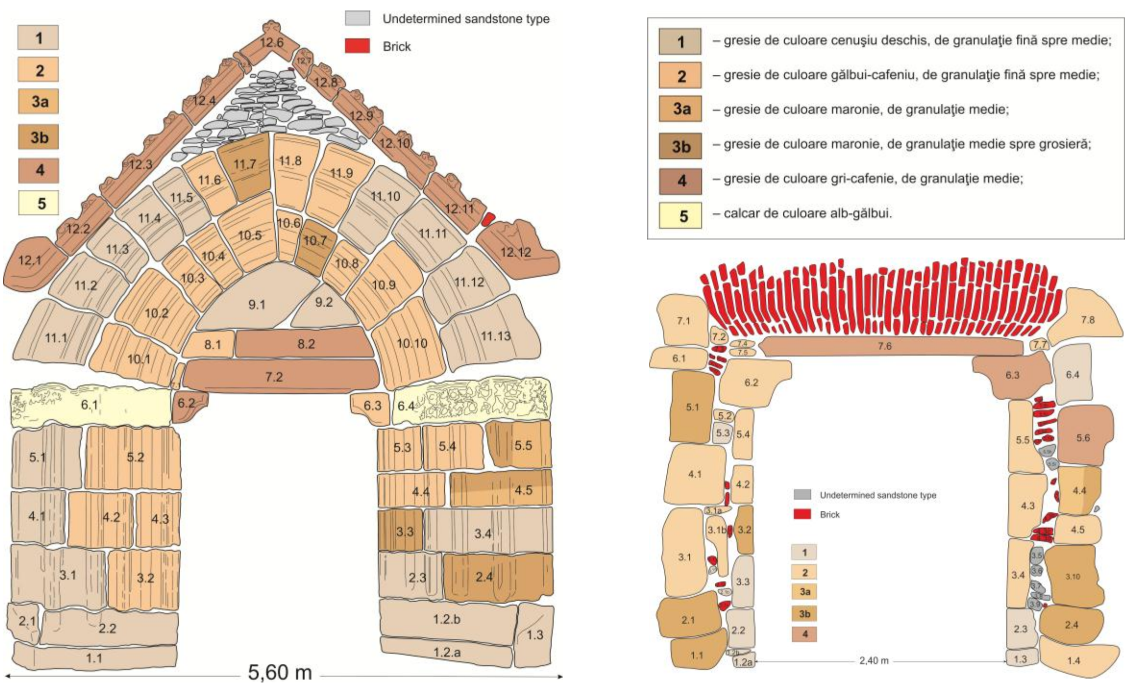

Fig. 1. Rock type mapping – Portal (western/eastern)

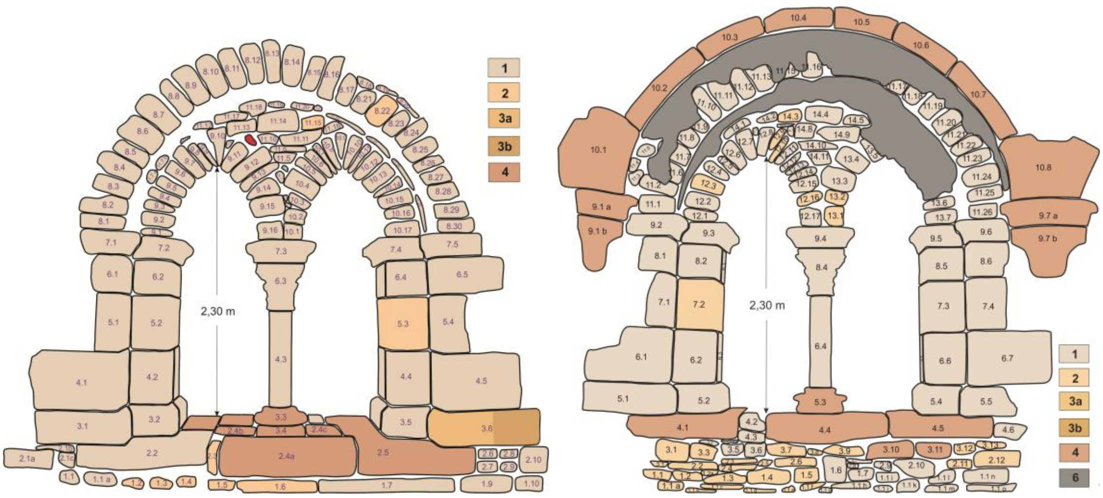

Fig. 1. Rock type mapping – Geminate window (western/eastern)

The type 1 sandstone is mainly used at the geminate window (Fig. 2). For the portal this is used especially in the blocks that form the outer arches and columns, the inner ones being built mostly with sandstone type 2 (Fig. 1). Only a few blocks of sandstone are the type 3a and 3b and occur mainly on the lower right side of the portal. Sandstone type 4 is tougher and more compact. It seems that it was used in areas with high structural tensions and for the upper blocks of the portal. In the eastern part of the portal a pattern of the use of different types of sandstones is not obvious.

4.2.2. Clash test (sound velocity) mapping

To a possible restoration project, the blocks or parts of blocks marked in red are those that would be replaced and / or treated first, while blocks / parts of blocks marked in green require minor conservation.

The western parts can have similarities between the blocks at the top, both at the portal (Fig. 3) and the geminate window (Fig. 4). Upper blocks have low sound velocity and therefore a higher degree of weathering. At the western portal it stands out the weathering of protruding architectural details and arches. The blocks located underneath the arches where sandstone type 4 was used, are less weathered.

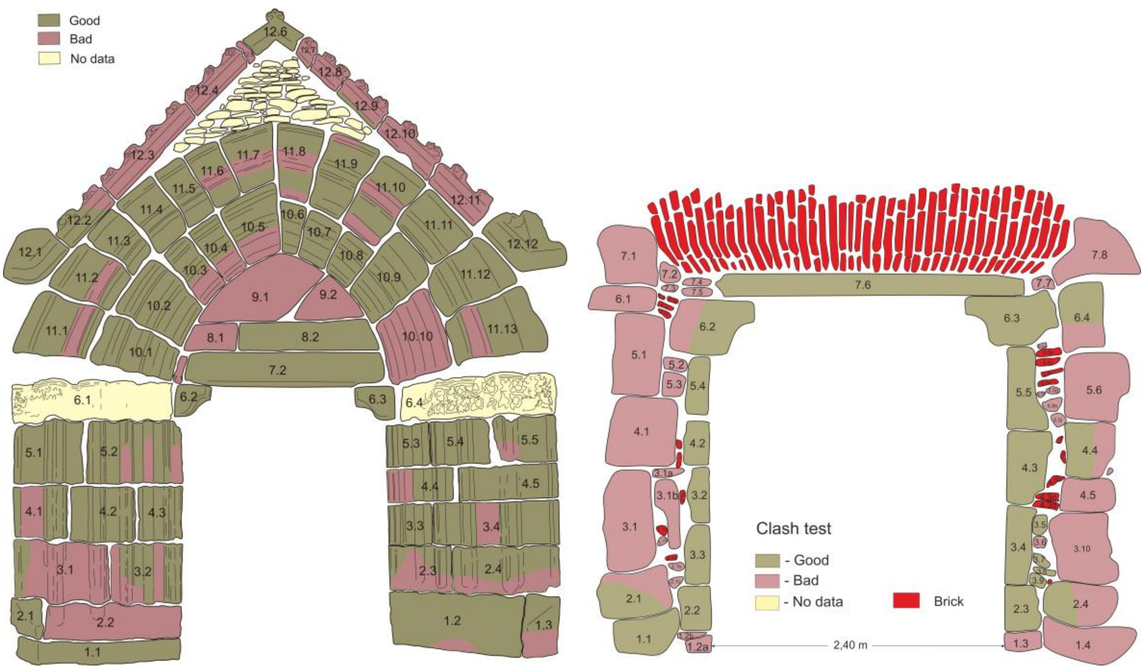

Fig. 3. Clash test mapping – Porta (western/eastern)

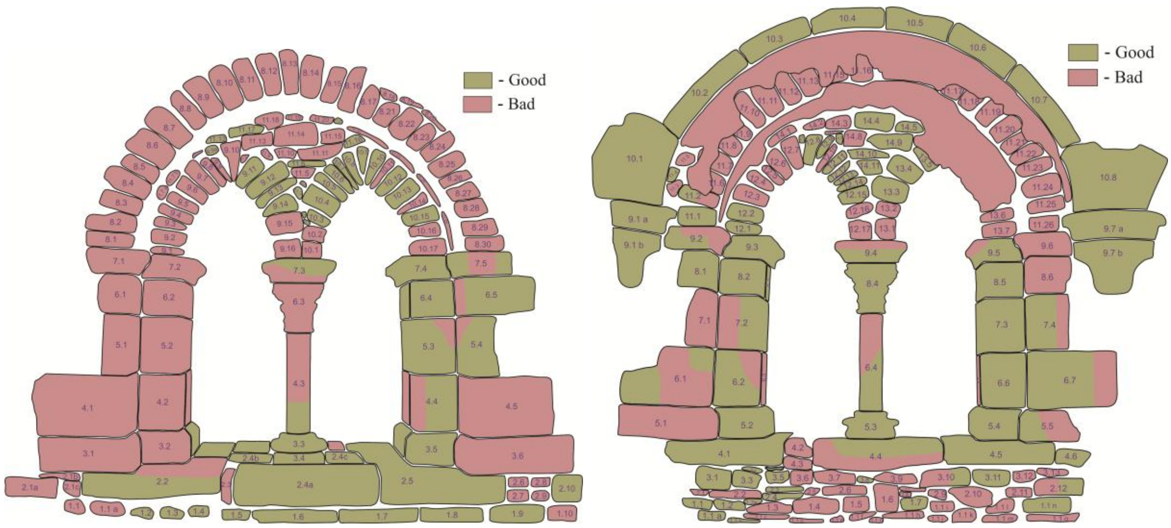

Fig. 4. Clash test mapping – Geminate window (western/eastern)

Blocks in the eastern part of the portal are heavily damaged, as they were affected by fire in the history of the monument (Fig. 3). On the western side of the window, a difference between blocks on the lower left and on the right side can be seen (Fig. 4), as shown also at the western portal. The difference in resistance for the sandstone types 1 and 4 to the factors determining intensive weathering is highlighted at the eastern part of the geminate window (Fig. 4).

4.2.3. Moisture mapping

At the western portal, differences between values from the left and right side are due to their orientation. Upper blocks (Fig. 5), more intensely affected by insolation processes have lower humidity. The columns and arches, being prominent, have higher values and the right side of the portal has the highest humidity. At the eastern portal humidity values are heterogeneous.

The western part of the window (Fig. 6) is more humid than the eastern surface. Higher moisture on lower position blocks of the window is most likely due to upward migration of capillary water. The eastern part of the window has the lowest values at the top, both to the arcade and the parts that are still covered with mortar.

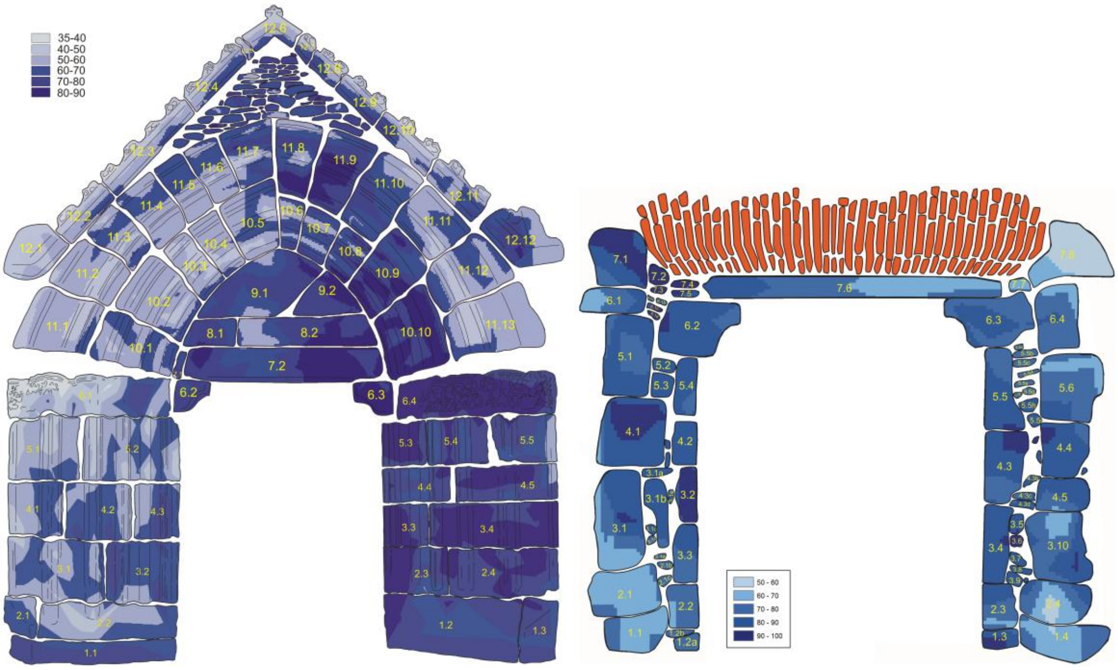

Fig. 5. Moisture mapping – Portal (western/eastern)

Fig. 6. Moisture mapping – Geminate window (western/eastern)

4.2.4. Macroscopic analysis of weathering processes

Western parts are affected by microbiological colonization due to moisture and exposure to climatic factors that can generate crusts. This environment is suitable for colonization by plants as well. Other processes that occur at the geminate window are exfoliation, granular disintegration, rounding and notching, flaking and scaling due to expanding clay minerals. Dissolution of carbonate components can cause detachment of crust, breaking out and back weathering.

On the left side of the west portal, the intense alveolar weathering of the sandstone blocks (Mihăilă, 2010) leads to granular disintegration and back weathering of protruding architectural elements.

On the western oriented parts, sandstone blocks are especially affected by microbial weathering while at the eastern parts have commonly crusts formation at the surface, detachment of crusts and coloration processes.

Oxidation of iron minerals may cause reddish coloration of the rock, due to fires that affected the building, especially on the eastern side of the portal.

4.3. <u>Laboratory analysis</u>

4.3.1. X-Ray diffraction

4.3.1.1. Mineralogical composition

The minerals identified in sandstones by X-ray diffraction analysis (Table 4) are quartz, calcite, feldspar (plagioclase and microcline), gypsum and phyllosilicates in varying proportions.

Tabel 1. The mineralogical composition of sandstones, after X-Ray diffraction

Sample	Calcite (%)	Quartz (%)	Plagioclase (%)	Microcline (%)	Gypsum (%)	Phyllosilicates (%)	Micas	Kaolinite/ Chlorite
C 1	38.6	40-50	10-12	5-7	-	7-12	XXXX	XX
C FGE 1	39.1	40-50	10-15	5-7	-	7-10	XXXX	X
C FGW 3	36.1	40-50	5-7	3-5	5-7	7-12	XXX	XX
FGE 2	37.6	45-55	7-10	5-7	3-5	10-12	XXXX	X
FGW 2 Cr	36.6	45-55	5-7	3-5	-	5-10	XXXX	X
FGW 4	33.3	45-55	5-7	5-7	-	10-15	XXXX	X
P 1	36.5	45-55	7-10	3-5	-	7-10	XXX	X
P 6	35.1	40-50	8-10	3-5	7-10	10-12	XXXX	XX
P 7	35.1	40-45	15-17	7-10	-	10-15	XXXX	XX
P 7 Cr	30-35	45-55	10-12	7-10	2-5	5-7	XXX	X
PE 3	35.1	45-50	10-15	7-10	-	5-7	XXX	X
PE 4	34.0	40-50	10-12	3-5	3-5	5-10	XXXX	XX
PE 7	37.6	45-55	10-15	3-5	3-5	5-7	XXX	XX

4.3.1.2. Clay minerals

Micas, kaolinite, chlorite and montmorillonite have been identified. All studied samples have high amount of micas as they are predominant. Kaolinite is also present in all studied samples, and chlorite has a lower percentage.

Smectites appear in all analyzed samples in the form of 12Å montmorillonite. We also identified 14Å montmorillonite at the geminate window, which confirms that the sandstone used at the window and at the portal were probably taken from different horizons. The expansion characteristic of the smectites causes intense weathering of the rocks containing them.

4.3.2. Grain size analysis

After the grain size measurements we were able to calculate de sorting coefficient of the sandstones, ranging from 0,55-1,07 (poorly sorted – moderately well sorted), as well as the medium grain size (117-396 μm).

4.3.3. Optical microscopy

The main mineralogical components are highlighted by X-ray diffraction. By the study of thin sections we identified also the heavy minerals, as they are important in confirming the area of provenance of the used material (Mihăilă, 2011). The samples are feldspathic litharenite with carbonate cement and bioclasts (Mihăilă, 2009). Most rock fragments identified in the studied sandstones are of metamorphic origin, but igneous or sedimentary lithoclasts may also occur. Among the heavy minerals we identified garnet, zircon and epidote occur frequently, but subordinate rutile and tourmaline can also be found.

Various bioclasts were identified, especially foraminifera, represented both by benthic and planktonic forms. Benthic foraminifera Nonion sp. (?) are common in Sarmatian. The provenance area of the sandstones used at Cârţa is also confirmed by some planktonic foraminifera. We also found biogenic alochemes fragments like mollusc shells, corallinaceans and echinides, and sometimes altered briozoas.

4.3.4. Microscopic analysis of weathering forms

Many of the studied samples have different fissures and fractures running around different clasts, probably produced due to dissolution or mechanical processes. Fissures around some clasts and temperature fluctuations can determine granular disintegration. Fractures parallel to the surface can cause flaking at the surface of the material. Sometimes high humidity can lead to the formation of thin carbonate crusts. A thick layer of lichen colonization may occur on the west oriented blocks. Radial crystals of gypsum that occurs as secondary product can form dark crusts at the surface. On the eastern portal samples glauconite shows brown color, unlike the rest of the samples where it is typically green. This indicates weathering caused by historical fires.

4.3.5. Scanning electron microscopy (SEM)

Weathering by granular disintegration occurs especially at the samples from the eastern oriented blocks. Some angular hollows that occur at the surface of the calcite crystals represent $CaCO_3$ dissolution due to infiltrating water. At the western blocks colonization by lichens is a commune process and the penetration of their filaments determine the mechanical disintegration at the surface of the rock.

4.3.6. Porosity

Inter-particle porosity (between clasts) proved to be predominant for the studied sandstones. Values range from 1.35% (source area) to 2.57% and 6.3% at the eastern and western blocks.

Average inter-particle porosity in the samples from the building (3.46%) is slightly higher than that of the source area, which is actually secondary porosity resulting from chemical alteration processes (eg dissolution of $CaCO_3$) or thermal expansion (physical disintegration).

4.3.7. Ultrasonic velocity measurements

Ultrasound velocity was measured both perpendicular and parallel to the stratification, where this was possible.

Low values of ultrasound velocity perpendicular to the stratification and high values of anisotropy in sandstones are the results of the weathering processes affecting the rock. Thus anisotropy values are low for the sample from the provenance area (1.03) and medium-high for the weathered fragments (1. 08 to 1.25).

5. Discussions on restoration / preservation methods

Restaurateurs, architects and researchers from various fields must work together to find the most suitable methods. Any modern techniques can be used for preservation and consolidation of the monuments, as long as their efficiency is proven by scientific data and the common methods prove inefficient. Some physical and chemical methods of maintenance / cleaning are presented, as well as their advantages and disadvantages, making reference to the possibility of using them at Cârţa.

6. Conclusions

Cârţa Cistercian Abbey has a great value, both because of its long history, since it dates from the XIII century, but especially due to the high influences on the Gothic in Transylvania. The monastery has underwent numerous damages over the years, being now mostly in the form of ruins. Detailed study of the material used to raise the monastery is necessary as the basis for the possible restoration and conservation of the former abbey.

For architectural details, built with dimensional building stones, they used the same type of rock. The studied sandstones, both from the monastery walls, and the provenance area are feldspathic litharenite with carbonate cement and bioclasts. It was confirmed that the chapter hall’s wall and the portal were built at different times, the latter being built after the Mongol invasion and shows mature Gothic characters. The attention to details is not so well observed at the eastern part of the portal, because the sandstones used have different grain sizes and different degrees of sorting, perhaps because the blocks were supposed to be plastered as they were located inside.

The studied sandstones contain overall the same minerals, in slightly varying proportions: quartz, calcite, plagioclase feldspars, microcline, phyllosilicates (with a higher concentration of micas) and heavy minerals (zircon, garnet, epidote, rutile and tourmaline). Gypsum appears just as a secondary mineral, but is important because it determines severe weathering. It was identified in two crusts and four highly weathered sandstone blocks.

Samples collected from the portal and the window were compared with those taken from Colun, where the sarmatian clacareous sandstone outcrop. The Sarmatian age of the sandstones from the walls is confirmed by the identified foraminifera. These sandstones are similar to Colun in terms of mineralogical composition, including the heavy mineral content. Unlike the Colun sandstone, a slight difference in grain size is seen in some blocks used in the portal, these being slightly coarse. But this doesn't infirm Colun village as provenance area for the lithic material.

Samples from Colun have lower porosity values than those weathered, both inter-particle and total values. They have no anisotropy, unlike those taken from the decayed walls of the monastery.

Macroscopic study of weathering processes reveal degradation belonging to all groups defined by Fitzner & Heinrichs (2000): Loss of stone material, Coloration / Deposits, Detachment and Fissures / Deformation.

Western-oriented walls provide optimum conditions for biological colonization that occur due to the humidity. Moisture also determines swelling of clay minerals, causing mechanical stress and weakening the rock structure, thus increasing permeability and leading to exfoliation and granular disintegration. Insolation, combined with calcite dissolution can cause the weakening of inter-granular bonds increasing the fissures and generates larger pores. This in time leads to loose of material by breaking out. Oxidation can cause color changes. For the western portal, alveolar weathering is a very visible process that occurs. At the eastern crusts and detachment of crust commonly occur, as well as coloration most probably induced by oxidation. This occurs due to the historical fires that affected the building.

Microscopically, most of the samples present fissures and fractures around clasts. There have also been identified other types of secondary porosity, mostly due to carbonate dissolution of clasts, which are amplified by fracture zones. Fractures parallel to surface rock allow green lichens to settle in, which leads to intense biological colonization. Black crusts formed by radial growth of gypsum crystals can also appear on the surface of sandstone, their color being given by carbon particles in the atmosphere that results primarily from burning fossil fuels. These weathering processes (dissolution of calcite, granular disintegration and intense biological colonization) are detailed by SEM images.

The identified clay minerals strongly influence the deterioration of the sandstone due to their swelling/ expansion property. Smectites are represented by montmorillonite, which in some samples is second from the total phyllosilicates content, after the micas.

Strong weatherings are the result of several factors that have direct impact on the rock: high anisotropy of sandstones, low porosity, compactness, $CaCO_3$ content and clay minerals. Add to this the external factors (climate, geographical orientation, human impact etc.) are causing moderate to severe damage of the building material used at Cârţa Cistercian monastery.

For preservation and restoration of the sandstones several techniques and methods can be used, each with advantages and disadvantages. Regardless of the method proposed to consolidate and protect the lithic material, two important aspects have to be taken into account: rock behavior shortly after treatment and long-term monitoring. This is necessary especially if you the preservation of the material would be performed by the chemical methods described. We suggest that if applying physical methods this should only be done on those portions of the wall without significant architectural details and not at heavily damaged parts; to those areas most suitable is laser cleaning, although it is more expensive.

To propose an optimal method of conservation must take into account the economic factors and the possibility of an actual restoration project of the monument, in addition to the study presented above.

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