Chapter

Introductory Chapter: Environmental Characteristics of a Dobrudja Famous Archeological Monument

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1. Introduction

Assembly, dated IX–XI centuries is located in a hill of chalk cliff into a Roman career style, with churches, galleries branched vaults, housing the tombs [1]. Facings are inscribed with symbolic designs and different scenes and a large number of inscriptions. Some of these are palaeoslavonic and Cyrillic and some are written in Glagolitic or in Greek, but mostly in an enigmatic writing that could not be decoded so far [2, 3] (**Figure 1**).

1.1 Monument characteristics

After the discovery, in 1957, the assembly elements were partially crushed and the rocks have been repositioned in a structure of reinforced concrete and cement mortar. A protective building of concrete has been built for more than half of the site; the rest remained under provisional protection of wood and tar paper. These constructions have not assured proper microclimate, especially in the facing incised [4].

The monument is in an extremely critical situation, taking into account the sensitivity of the chalk rock; it was accelerated and damaged after the assembly discovery. For this reason, it is imperative exceptional measure for protection.

Since 1960, construction of a permanent building protection was expected to protect the whole site in front of adverse weather conditions, variations in temperature and humidity and other factors that could compromise the monument.

Cave monuments are conducted on an area of 2684 sqm. They are protected by a permanent building, on an area of 924 sqm. This construction is made of reinforced concrete with a roof inclined at 30°, applied to the building built between 1971 and 1974. The remaining 1760 square meters were covered with a temporary protection structure made of wood and reed, covered with tar paper. This construction was supposed to protect the monuments of rain, snow, wind and also of changes in temperature and humidity.

Currently, the wooden structure of the building was repaired under provisional protection, and cardboard asphalt was replaced with polycarbonate enclosures in summer 2006 (**Figure 2**).

The church monuments carved in the Chalk Mountain was strengthened in broken or degraded areas by frost infiltration in reinforced and enamel-coated concrete. Cracks that have been injected with cement and sand mortar have a dark gray appearance on the chalk surface, like a splash.

Figure 1.
The interior of the churches and crosses, figures incised in the chalk wall.

Figure 2.
Provisional protection structure.

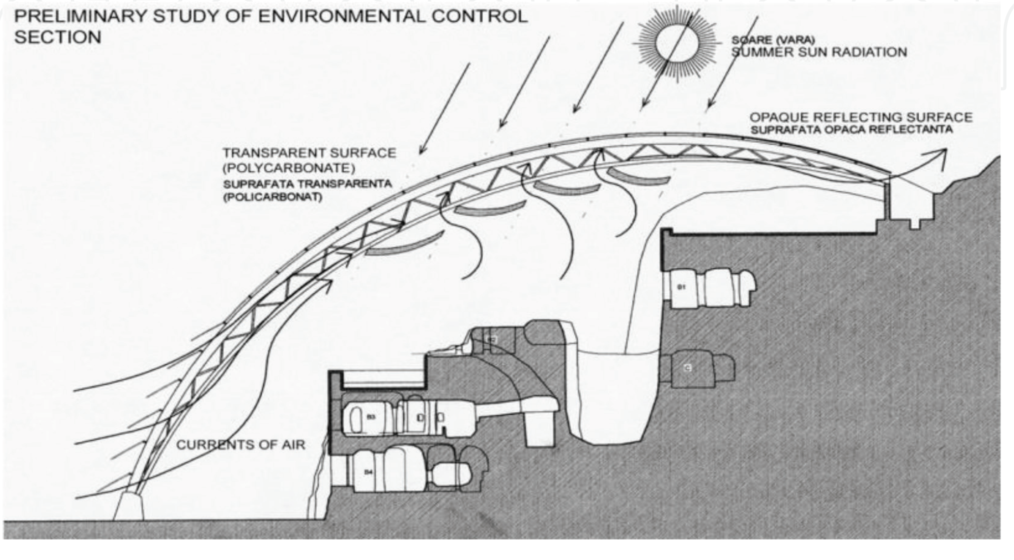

Figure 3.
The scheme of the polycarbonate enclosure.

The original protection plan, of the 1960s, of the monument building was carried out along of the chalk mountain, covering all caves, divided into seven sections corresponding to the monument's interest areas, respectively to the caves. Unfortunately, this project was interrupted, from a bad administrative conjunction. Since 1989, the project was revived to achieve (**Figure 3**). In 1994, they started provisional construction works for rehabilitation, with a progress noted especially in steep 2009. Currently, culvert was repaired to prevent rainwater from drain the entire downstream side directly inside the monument site. The roof still shows degraded areas. Since 2010, the monument is only in the scientific researches of specialists and prestigious experts for finding an interdisciplinary rehabilitation solution.

2. Experimental part

The investigations proposed are:

1. evaluation of the characteristics of rock samples by laboratory analysis;

2. determination of compressive strength of fresh and altered rocks;

3. mineralogical analyses for monitoring the extent of alteration area inside and surrounding of area of interest; and

4. determination of freeze-thaw durability.

2.1 Geophysical measurements

By geo-radar measurements type, a picture of the structure of the subsoil, especially when settling land, has been obtained.

The electrometric method "electric survey vertical" (EVS) and a gravimetric method have been used. The following measurements have been done: the presence of the fluid in saturated or unsaturated rocks, porosity and permeability of rocks, freeze-thaw durability, chemical content of fluids in rocks from the basement, resistivity changes due to different chemical and physical conditions.

Also, the chalk massive structure, changes in the structure and uniformity, the presence of voids, or areas of vulnerability may offer important information.

Geophysical work program should have the following objectives: geophysical detail to the foundation of the old and new buildings; geophysical detail of the state geological massif chalk in the archeological monuments; geophysical characterization of chalk massif state; geophysical permanent control of water accumulation condition in career; geophysical investigation to establish the area hydrogeological conditions; and investigations of the geophysical and hydrogeological conditions in the warehouse waste.

A total of approximately 150 EVS locations with investigating depths from 30 to 150 m, made with different equidistance, were performed according to the degree of detachment determined by the frost-freeze procedure for chalk pattern for 20 series, which were analyzed by repetitions: dry at 105°C to a uniform mass (M 1) for an hour, submerged 15 min in distilled water, removed from the water, cleaned with a damp canvas, dried up 3 h at 20°C and measured (M 2). After that the samples have been introduced into the freezer for 2 h at −18°C, taken off and immersed in water, thawed, and after that chalk samples are weighted (M 3), [5–7].

Deteriorated chalk measurement was estimated with the formula: % μg = (M 2 – M 3/M 1) × 100, where μg is the freeze factor [8, 9].

The examination of thin petrographic sections, is carried out with a microscope like Leitz polarizer, which is very useful to characterize properties of structure, minerals, cement composition, and the digenetic characteristics of the sample, and then explored with a polarized microscope.

2.1.1 From hydrogeological point of view

The proposed investigations refer the groundwater conditions' hydro-geological site near the monument, water accumulation in career and possible leakage of leachate to landfill career. For all these, it has been achieved six boreholes to depths of 15–20m, located outside the site with research role (**Figure 4**). Except these, the chemical analysis of pre-elevated water from drilling and the analysis of physical properties of the materials present in drilling have been achieved.

The obtained results are as follows: porosity—0.5–13.5%; and degree of saturation—ratio between natural humidity (Wn) and the humidity of the same rock but saturated with water (Wsat). In our case, this parameter has the value of 0.3–0.994; density: 2.55 kgf/dm^3; apparent density: 1.9–2.8 kg/dm^3; and strength = 30 kg/cm^2 (**Table 1**).

2.2 Petrographical and mineralogical analysis

From the compositional point of view, the piece of chalk is a limestone, which is characterized as a biological clay, containing a multitude of limestone sediments, porous with small granularity and extremely fragile. The chalk sample has an organogenic chemical composition consisting of calcium vaterite and mineral clay, with a chemical formation comprising iron oxides and sediments. The wall is composed of calcium carbonate in a proportion of 90% and silicon dioxide [10]. In some places, there are traces of shells and shells of mollusks and ostracods, foraminifera, radiolar and diatomee, sponges of spongiers and radiolars, as well as crushed animal bones. Analysis of petrographic microscopy confirms that vaterite is generally unstable, except that it becomes stable below 10°C when the framboid is present inside the organic structure in the presence of CO_2 [11]. These framboid is in fact a conglomerate of smaller, especially spherical elements, having a dimension size varying between 36 and 150 nm [12, 13] (**Table 2**).

Figure 4.
The photo of naos.

Sensor location	Relative humidity			Temperature		
	Minimum (%)	Medium (%)	Maximum (%)	Minimum (%)	Medium (%)	Maximum (%)
1/inside	49.9	68.5	75.8	−1.0	6.5	17.4
2/inside	65.7	77.4	95.9	−1.5	6.8	18.2
3/inside	63.7	83.2	90.9	0	4.8	11.7
4/inside	55.4	77.4	96.2	−2.2	6.8	17.7
5/inside	—	—	—	—	—	—
6/inside	67.3	84.6	100	−1.2	6.0	15.8
7/inside	63.5	82.2	97.9	−2.4	6.9	19.1
8/inside	—	—	—	—	—	—
9/inside	55.4	76.5	87.9	−0.6	6,5	13.9

Table 1.
The humidity and temperatures variations for Basarabi church (naos).

2.2.1 Freeze-thaw durability

When water penetrates through the cracks or breaks of stones or through capillary spaces, it will freeze in winter and the stone will be under great pressure that will cause tearing or splitting, especially if the rock is weak. Chalk stone is considered to be very affected by frost, because it has many empty spaces in its structure, allowing the water to penetrate deep, being a rock with a granular structure with a weak, no frost resistance at all. In combination with these factors, the presence of salt in water, given the generally damp marine environment of the site, easily leads to the disintegration of the rocks [14, 15] by lowering the frost, generating longer periods of thawing, which lead to the creation for longer periods of moisture absorption. This test method has no absolute value but is a variable that provides an indication of frost and thaw resistance, so it does not serve as the only basis for determining the durability of rocks [16, 17]. After the completion of 20 cyclic frozen-thawed series, the weight loss of the samples was determined as shown in **Table 3**.

Elements	Internal (ppm)	External (ppm)
Aluminum	554	196
Strontium	317	496
Calcium	94,700	96,700
Barium	1.00	16.00
Manganese	169	217
Iron	379	116
Magnesium	132	1304
Sodium	837	1746
Zinc	2.5	82
Copper	0.3	3,5
Potassium	529	127

Table 2.
The elements' focus inside and outside the church (minor elements).

Identification of samples	Initial weight (g)	Final weight (g)	Weight loss
Chalk	54	47	7

Table 3.
Results of mass loss by cooling and thawing.

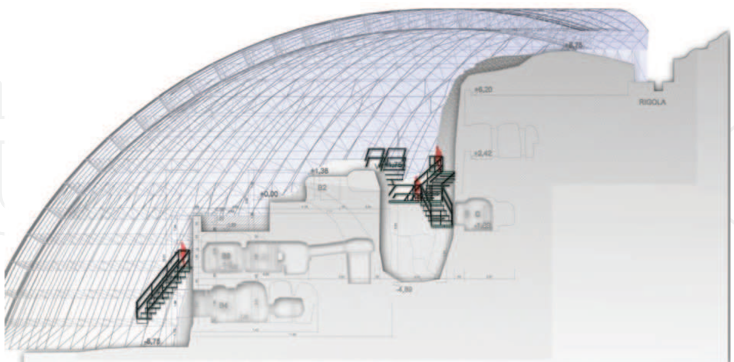

Figure 5.
The section through the Chalk Mountain.

The viable solution remains with the polycarbonate enclosures, with adequate respiration air flux (**Figure 5**).

3. Conclusion

One may conclude that our preliminary study of environmental characteristics and control, geological, hydrogeological and geotechnical is very important for research to rehabilitation of Basarabi Chalk Churches by innovative solutions based on nanostructured consolidants for preserving and polymer enclosure for protection with real chances for practical application.

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Conflict of interest

None of the authors have any competing interests in the manuscript.

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References

[1] Ion RM. The churches of Basarabi-Murfatlar. In: Scientific Aspects on the Actual Stage in ArheoVest, No. I: Vol. II: Interdisciplinary Methods and History. Szeged, Timisoara: JATEPress Kiadó; 2013. pp. 713-725

[2] Opreanu M. Basarabi Cave Ensemble (I). Murfatlar, Constanţa, Arhitext; 2002. pp. 34-36

[3] Opreanu M. Basarabi Cave Ensemble (II). Murfatlar, Constanţa, Arhitext; 2002. p. 19

[4] Barnea I. The Murfatlar cave monuments (Basarabi), Constanţa. In: Sud-Est 30. 1997. pp. 54-59

[5] Ion R-M, Bunghez IR, Pop S-F, Fierascu R-C, Ion M-L, Leahu M. Chemical weathering of chalk stone materials from Basarabi churches. Metalurgia International. 2013;**18**(2):89-93

[6] Ion R-M, Fierascu RC, Fierascu I, Senin RM, Ion ML, Leahu M, et al. Influence of Fântânița Lake (Chalk Lake) water on the degradation of Basarabi–Murfatlar churches. Engineering Geology for Society and Territory. 2015;**8**:543-546

[7] Ţurcanu-Caruțiu D, Ion R-M. Pre-restoration investigations of the Basarabi chalk monument diagnosis, treatment and implications. European Scientific Journal. 2014;**3**:124-134

[8] SR CEN/TS 772-22:2009. Test methods for masonry. Part 22: Determination of freeze/thaw resistance of clay masonry elements. 2009

[9] SR EN 14617-5:2012. Agglomerated stone. Test methods. Part 5: Determination of frost and thaw resistance; 2012

[10] Ion R-M, Fierascu RM, Ion ML, Leahu M, Turcanu-Carutiu. Nanomaterials for conservation and preservation of historical monuments. In: Proceedings of EWCHP; Bolzano; 2013. pp. 97-104

[11] Pop S-F, Ion R-M. Thermal analysis of the chemical weathering of chalk stone materials. Journal of Optoelectronics and Advanced Materials. 2013;**15**(7-8):888-892

[12] Goudie A, Cooke R, Evans A. Experimental investigation of rock weathering by salts. Area. 1970;**2**:42-48

[13] Ion R-M. Nanomaterials for restoration and conservation of historical monuments. In: New Applications of Nanomaterials. Romanian Academy Publishing House; 2014. pp. 99-112

[14] Ion R-M, Turcanu-Carutiu D, Fierascu R-C, Fierascu I. Chalk stone restoration with hydroxyapatite-based nanoparticles. Scientific Bulletin Materials and Mechanics. 2014;**9**(1):54-70

[15] Perez Ema N, Alvarez de Buergo M. Adverse effects arising from conservation treatments on archaeological sites: Theory, practice and review. Coalition. 2013;**23**:14-23

[16] Williams RBG, Robinson DA. Frost weathering of rocks in the presence of salts—A review. Peffilafrost and Periglacial Processes. 1991;**2**:347-353

[17] Jerwood LC, Robinson DA, Williams RBG. Experimental frost and salt weathering of chalk. Earth Surface Processes and Landforms. 1990;**15**:611-624