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APPLIED GEOLOGY: MINERALOGY AND PETROGRAPHY OF THE BUILDING MATERIALS OF ARAČ RUINED CHURCH (VOJVODINA, SERBIA)

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Abstract. The Arač (Aracs) ruined church is located Vojvodina on the left side of the River Tisa. It is an unique standing medieval church monument of Serbia. As a part of the restoring and conservation works, among 2009–2011 the samples of stone and man-made materials of this building were taken and analyzed. Using geological methods, the origin, the technology and the weathering processes of these materials were emphasized. Thus, the most probable origin of the stone material was Buda Mts., close to Budapest; the clayey-silty material for the bricks came from the surrounding old Tisa floodplain sediments, the lime for the binding and rough-casting material was obtained from carving by-products of the stone material and the sand of mortar and plaster was transported from the alluvia of the River Mureş. The microscopic study proved, that two or more plastering and painting phases were executed. The weathering of the building elements began after the outbreak of fire what destroyed the wood roof of the church. On the stone elements, after the fire and the frost caused fissuration, by the leaching of carbonate, important loss of material happened (separation of leaf-like crusts, the smoothing of carved ornaments). On the bricks, the pore fillings with hygroscopic salts from the capillary groundwater contribute to the crumbing of them. On the stones and the plasters, the effect of bio-degradation (by root acid caused corrosion and leaching) was found. These observations give information for specialists to select the appropriate materials for the restoration and the conservation of this important historical monument.

Key words: Vojvodina, Arač, monument restoration, limestone, brick composition, mortar composition, Mureş sand alluvia, Ca-oxalate

1. INTRODUCTION

It is known, that the archeologists, and, the restorers of historical monuments as well make use constantly geological methods to know the composition of different natural or man made materials of the objects on which they are working. That is to say, these materials, both in natural or in artificial environment can be characterized with the similar mineralogical-petrographical parameters and follow the same transformations, as the outcropping rocks and sediments. In the case of old architectural objects, during many hundred years of exposition the weathering processes both in chemistry and mineralogy are coming close to the same transformations that in outcrops, opened during "geological" times. We underline, that different man made building materials as brick, mortar or plaster of these monuments behave similarly, than natural stones. For this reason, the restorers need assistance of applied geology, both in planning of their works and in execution of them. In this paper, we intent to present an application of these principles in the case of Arač ruined church.

2. LOCATION, SHORT HISTORY

The Arač ruined church - a unique standing medieval church of Serbia - is situated in the left side of River Tisa, in the middle point of the triangle among Novi Bečej, Torda and Novo Miloševo, at 80 m about sea level (Fig. 1). That is visible out of the way from the Novi Bečej–Bašaid road as high red walls piercing the horizon of this flat field (Plate 2, photo1).

Based on Eneolitic ceramic finds, the history of this site begun from Neolithic period. Roman carved stones, sepulchers and ceramics from the III–

IVth century A.D. were found, too. After the excavations of Sándor Nagy (1971–1976), under the ruins, the foundation of older, smaller church was found, which was dated back to the XIth century.

Figure 1. Location of Arač ruined church.

The precise age of the ruined church Arač is unknown yet. Comparing the architectural style of this building with other old churches (Henlszmann, 1871; Henlszmann & Aracsi, 1876 Gercze, 1896; Bakó unpublished report 1993), it is probable, that the construction began in 1230. The excavations proved, that close to the church, a priory and a village were stood. The name of this settlement was forgotten - the toponym Arač (Aracs) appears only from the XVIIIth century. Other names are Pusztatemplom and Góthegyháza (Kalapis, 1995, Raffay, 2005).

In present days the monument and the surroundings are owned by the Vojvodina Autonomic Region and by the Regional Institute for Protection of Historical Monuments, Novi Sad, as a highly protected historical object.

The works for preservation and restoration of the church begun in 1970 and has continued until 1980. Repairing the damaged Northern and Southern walls at 2.5–3 m high, the Western, highest wall was stabilized. Now, an extended restoration project is prepared. Our research is giving important information about the origin and the actual state of the ancient building materials for these restoring works.

3. TARGETS AND METHODS

The fundamental principle of the restorers is that after the put the ladders the walls the nature and the characteristics of the restoring object are mainly known, including the composition of their building materials (Toracca, 2009). Now, the specialists have the possibility to use modern instrumental and technical methods, including geological ones, to know the nature and the properties of building materials.

Thus, at the beginning of 2009, by the support of Bethlen Gábor Funds and with appoint of a few scientists, the sampling, the analytical works and the interpretation of the results was finalized. As the first conclusions, the restoration works were presented in the license thesis of one of the authors In this period, samples were taken from stone material, bricks, plasters, mortars and painted films. The samples of different points of the ruins come from the main architectural components of the building (walls, absides, pillars and rosettes), and from the surrounding soil level with water soluble salt content, and they were documented by topographic measurements and digital photos. By analyzes of thin sections and bulk materials, optical, X-ray, SEM the chemical, mineralogical-petrographical, structural and textural peculiarities of these materials were evidenced. According these data, the origin of the stone and the sandy-silty material and their transformation in time, i.e. the degree of the weathering were emphasized.

The sampling and the analytical works were coordinated by the Restoring Institute of the Hungarian University of Fine Arts, Budapest under the control of the Regional Institute for Protection of Historical Monuments, Novi Sad.

4. ANALITICAL RESULTS

The architectural elements of the church were build up from carved stone pieces, of bricks, bonded with lime based mortar and covered by plaster and painted in different periods of time. These materials were analyzed using geological methods, as follows:

4.1. The stone material

This is known that the restoration could be successful only when appropriate materials are used for replace the damaged pieces, we examined the petrographical, structural and textural peculiarities of these rocks with care. For this reason, from different stone pieces, 19 thin sections were analyzed: two Triassic dolomitic limestone, 15 lipoclastic Late Eocene limestone and two Sarmatia politic limestone thin sections.

<u>Triassic dolomitic limestone:</u> Light pink, fine grained, massive, hard carbonate rock with small brown ferruginous spots. Moderate effervescence with HCl.

Under microscope, the samples appear as mosaic of 0.02–0.30 mm angular carbonate grains:

colorless calcite with dark powder clouds and yellowish, often zoned, hemihedral dolomite crystals. A few, 0.5–2.0 mm large sparry lenses and nests (diagenized shell fragments?) appear, and also, 0.02–0.08 mm thick veinlets with (secondary?) micritic filling.

Late Eocene bioclastic limestone: These rocks constitute the main carved stone pieces of the church. With naked eyes, the yellowish grey, hard, fine grained limestone appear homogenous, with little white and grey grains, reacting with HCl.

In thin section, these rocks are formed by extraclasts, bioclasts, carbonatic groundmass and secondary minerals.

The extraclasts are represented by angular, 0.02–0.12 mm quartz and feldspar grains, muscovite sheets, mica-schist, sericitic quartzite fragments, with <3% of the total amount.

The bioclasts are the fragments of different carbonatic organisms as red algae (thallum of *Lithothamnium, Lithophylum*), foraminifera (mainly *Miliolida*), worm pipe, bryozoa, echinodermata, ostracoda and mollusca shell debris, coprolitic pellets and algal lumps.

Beyond all question, the presence of the flower- and cog-wheel like *Holoturia* dermosclerites and of rests of the small *Numulites* (*N*. cf. *fabiani, N. oligocaenica,* plate 2, photo 3) situate these rocks in Late Eocene, i.e. in Priabonian stage.

The amount of the yellowish, coalescent, micro-sparry groundmass of these samples varies between 15-25% in packstone-type limestone and <50% in wackestone type limestone. The secondary minerals as veins and pore fillings are represented by sparry carbonate (calcite and rare dolorhombs), by fibrous limonite and by dark material (smut), gypsum and opal infillings.

Sarmatian oolitic (sandy) limestone. The samples are light yellowish grey, medium grained, medium hard, nodular, porous carbonatic rocks with small white points and grey sand grains. It reacts strongly with HCl.

In thin section, these rocks are built up by a loose agglomeration of oolites, oncolites, free sand grains, bioclasts and cementing mass.

The oolites are 0.2–0.5 mm concentrically zoned carbonate bodies with or without carbonatic (bioclastic) nuclei. The oncolites are various shaped sand grains coated by 2–6 carbonatic rims. The coated or the free sand grains are represented by quartz with metamorphic and volcanic origin, by fresh plagioclase and sanidine grains and by vesicular pumice fragments. The amount of the sand grains represents 10–15% of the sample.

The bioclasts are the fragments of foraminifera, bryozoa and mollusca shells, often covered by grey, fine grained algal lumps.

The oolites, oncolites, sand grains and bioclasts are cemented by touching and meniscus sparry calcite cement.

The Sarmatian limestone is characterized by high pore space, with irregular, Ø0.3–0.5 mm pores lined by hemihedral calcite crystals and by secondary gypsum and dark powder.

If the different stone pieces were simultaneously put in building, it is probable, that the different rock types were extracted and transported from the same place, or from quarries situated close. Therefore, Triassic dolomitic limestone, Priabonian bioclastic limestone and Sarmatian oolitic limestones in Carpathian Area appear together only in a single site: in Buda Mts., close to Budapest.

The basement of the Transdanubian Middle Mountains, including the easternmost member of them, i.e. the Buda Mts is represented by Triassic dolomitic rocks. The Upper Karnian–Norian aged Main Dolomite Formation outcrops along the right riverside of the Danube, from Kolos place (Óbuda) to Gellért Hotel and in the Ist., IInd. and XIIth. Districts of the Hungarian capital and on the higher parts of Tétény, Budaörs and Budakeszi localities as well. Here a lot of more or less extended quarries was functioned until the middle of the XXth century (Kisdiné-Bulla, 1984).

Largely outcropping zones of Priabonian aged limestone with small *Nummulites* rests are situated in Northern part of Buda. In the quarries what are in present day, this rock type was described close to Árpád bath, in Szépvölgy, in Kis Svábhegy and in Gellért hill (Jámbor et al., 1966).

The limy, oolitic Sarmatian level is known as the Tinnye Formation A lot of quarries opened on the margin of Tétény platform, at Budafok and at Sóskút. The last ones functions in present day as the *Früchwald* Stone Ltd.

Priabonian limestone with *Lithothamnium, Holoturia* dermosclerites and small *Nummulites* outcrops in NW Transylvanian Someş Platform at Ciocmani, Cuciulat, Letca, Răstoci, Glod and Poiana Blenchi (Lăzărescu, 1964), close to River Someş (as possible fluvial transport way), but here the Triassic dolomite, and the Sarmatian oolitic limestone are missing.

Badenian and Sarmatian aged limestones are known in Northern foreland of Poiana Ruscă Mts. (Romania), close to River Mureş, with rare oolitic beds, but here both the Prioabonian and the Triassic carbonate rocks are missing.

Miocene aged sandstone with carbonatic

cement occurs in Northern Fruška Gora, e.g. in Slankamen quarry (Stanojev, 2009).

These rocks differ both from mineralogical and structural point of view from the original stone material, that were used in the reconstruction in the 70s of the last century, without they previous analytic work.

Concluding, the most probable origin of the stone material of Arač church is Buda Mts., close to Budapest.

4.2. The brick

The red, well fired bricks were the main building elements of Arač church. Similarly to the monumental Western wall, all side of the church arises by massive brickworks. Nine brick samples were taken and thin sections, SEM photos and X-ray analyses were executed.

The brick pieces are hard, massive, but porous, with rough surfaces on that with naked eye, quartz, feldspar and dark sand grains, rare mica flakes, coal rests and Ø0.5–5.0 mm rounded dark red fired clay fragments are visible. On the surface, limy and smut films and mortar rests appear, too.

In thin section, the proportion between the sand grains and the cryptocrystalline groundmass varies from 1:1 to 1:10. The pore space was appreciated at 20%.

Sand grains are represented by metamorphic quartz, partly melted K-feldspar, Ø0.3-0.5 mm grey marl and dark grey (igneous?) rock fragments. Dark, spongeous grains (charcoal?) and rounded, fine grained lime concretions were identified, too.

The groundmass is a mixture of Ø0.01-0.05 mm angular quartz splints, fine mica flakes (or the rests of unfired clay minerals?), dark red (hematite?) pellets and reddish yellow, coalescent, often velvet-like, isotropic glass. In all samples, in the groundmass, Ø<0.005 mm anisotropic impregnation appears: fine grained carbonates, sulfates or other salts.

Apart from elliptic or key hole like pores as former gas bubbles, in the samples shell-like voids appear and they are traversed by long, straight channels of Ø<0.5 mm, with worm-like silica fragments and coal liners. They represent burned straw pipes and husk fragments.

In some pores, micritic, zoned carbonate liners or fillings were observed.

The X-ray analyzes of samples B1, C1 and T1 (Table 1), apart from quartz, feldspar and a small amount of calcite, the rests of the clay minerals (montmorillonite, illite, and chlorite) are evidenced.

The structure of the bricks are crypto-crystalline or vitreous, the texture is massive, stripped or fluidal. In the lighter or darker strips, the quartz splints, the mica flakes and the bubbles are oriented as well.

From these analyzes resulted, that the raw materiel of the bricks was the local silty clayey earth, i.e. the flood plain sediment of River Tisa, that reworked mainly the Pleistocene loess deposits. These ones are characterized by the presence of splint-like quartz grains and of micritic lime concretions.

The sand grains of brick mass seem to be similar to the sand grains of mortars (see chapter 4.3.). We note that in the mass of clay, fragments of the older, fired bricks or the waste material of the former kilns were mixed. The organic debris: root-, straw-, harle of hemp and husk particles (Plate 1, photo 4), and charcoal powder supply in the brick mass determine the rising of the porosity and the diminishing of the specific weight of them, without influencing mechanic properties (Büki, 2003).

Table 1. Mineral composition of some brick samples

Samples ® Mineral phases ‾	B1	C1	T1
Montmorillonite	6	8	6
Muscovite+illite	8	4	4
Illite/smectite mixed l.	2	2	
Kaolinite+chlorite	5	6	4
Quartz	47	48	53
K-feldspar	6	5	11
Plagioclase	4	5	6
Calcite	5	8	4
Fe-dolomite	2		
Hematite	4	5	4
Goethite		2	
Gypsum	3	3	3
Glauberite	1		tr
Amorphous	7	4	5
Total	100	100	100

Local lack of homogeneity and the stripped, fluidal texture of the bricks made possible to distinguish between these hand made medieval ceramics and modern, pressed ones. Due to the presence of unfired clay minerals, lime concretions and thin melting rims around the feldspar grains, the bricks were fired in artisan kilns, below 800°C (Kingerly, 1960)

4.3. Mortars and plasters

The bricks were bonded by limy mortar and at in past, both the internal and the external side of the walls were covered by one or more plaster coats. While the mortar was maintained between the bricks of the standing walls, now the plaster covers only on the highest part of the building, and in the inner side of the foot of the tower, as on little surfaces was preserved. From these materials optical, X-ray, SEM and petrophysical analyses were executed

The samples is made by a light grey, yellowish grey or pinkish, medium grained, slightly hard, porous material h reacting with HCl.

Under microscope, two grain size fraction could be seen: the coarser sandy material and the cement or the groundmass.

Both in mortar and in plaster samples, the cement and/or the groundmass are represented by fine grained or cryptocrystalline, coalescent carbonate, with clay mineral clouds or pellets and with nests of white, crumbly, sparry calcite. Recrystallized, sparry zones and bubbles with thin, euhedral calcite liners appear too.

The amount of the sand grains varies between 10–15% in plaster and 35–80% in mortar, but the mineral composition of them is identical. The main component is the metamorphic quartz and the quartzite. K-feldspar, plagioclase, muscovite, green hornblende, chlorite, rare grains of garnet, zircon, staurolite, rutile and titanite various rock fragments appear as well. We identified fragments of mica-schists, chloritic-sericitic schists, garnet bearing amphibolite, igneous rock, sandstone, claystone and limestone. The igneous rocks are represented by well rounded basalt (Plate 1, photo 5) and fresh or silicified–chloritized diabase grains.

In some mortar samples fragments of bioclastic limestone were found (Plate 2, photo 4). The diameter of the sand grains in mortar varies between 0.2–1.5 mm. They are rounded and sub-rounded. On a few quartz grains, thin homogenized, glass-like rim with contraction fissures appears.

By X-ray diffractometric analyzes of three mortar and one plaster bulk samples the presence of these minerals were confirmed. In three samples, peaks of edenite [$NaCa_2Mg_5AlSi_7O_{22}(OH)_2$] (Table 2) were identified. Among of carbonates, beside of calcite the dolomite appears (Fig. 2).

In the SEM photo of T2 plaster sample, the groundmass appears as Ø2–3 μm carbonate rhombohedrons with lamellar clay mineral flakes and rare gypsum prisms (Plate 1, photo 2).

Table 2. Mineral composition of plaster and mortar

Samples	H2	T2	G2	T2
Mineral phase	Plaster	Plaster	Plaster	Mortar
Calcite	30	23.5	25.5	67.
Dolomite	1	0.5		0.5
Quartz	40	49	36.5	20.5
Feldspar	20	20,5	21.5	7.5
Muscovite+illite	4.5	1.5	5	1
Kaolinite+chlorite	3,5	6.5	3.5	
Edenite	1	1	1	
Cristobalite		0.5		
Gypsum				0.5
Amorphous			3	2.5

Therefore the mortar and the plaster (and as well the bricks) contain the same fluvial sandy component. Because here in riverbed of Tisa not in present days and at the even not less in the past before the regularization, never been transported the coarser (sandy) sediments, so the sand supply of the mortars was coming from farther sites. Missing the smooth quartz grains and the well rounded carbonate ones, the windblown sand of the Danube-Tisa Interfluve could be excluded.

Because of the presence of metamorphic minerals of crystalline schists (including the high grade edenite), and diabase and basalt fragments, it is probable, that the sand of the binding materials (and of the bricks) is coming from Mureş alluvia, so

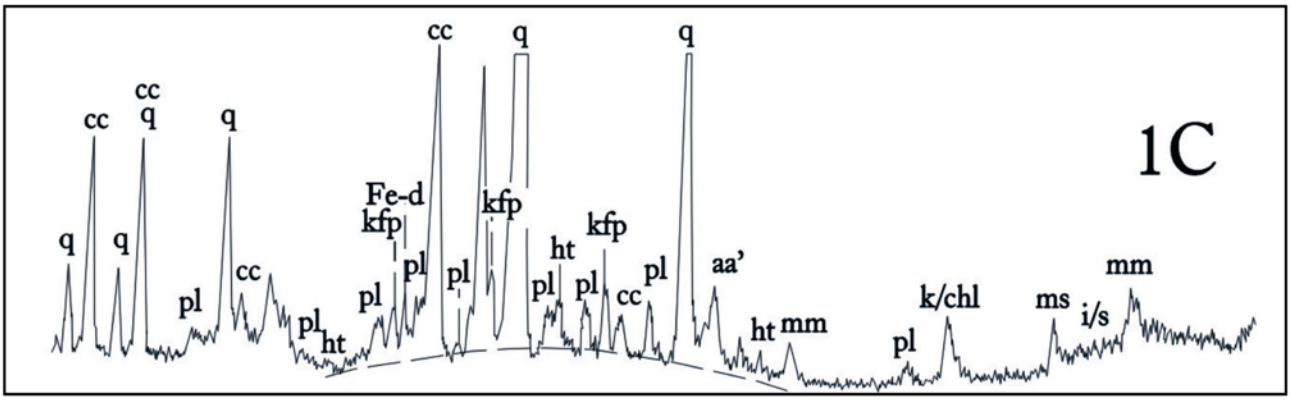

Figure 2. X-ray diffractograme of C1 mortar sample. aa', total clay minerals; cc, calcite; Fe-d, iron bearing dolomite; ht, hematite; 1/s, illite-smectite mixed layer; k/chl, kaolinite and/or chlorite; kfp, K-feldspars; mm, montmorillonite; ms, muscovite; pl, plagioclase; q, quartz.

much the more as the Archbishop of Csanád, the presumed builder of this church owned extended estates in Mureş valley, e.g. in Săvărşin and Bârzava area (Kollár et al., 2000).

What is the origin of the lime of the mortars and plasters? The limestone fragments in the sandy fraction of them is quasi identical with the stone material presented in chapter 4.1.

Thus, the fragments of these rocks, the by-product of carving, were fired and slaked, resulting lime paste with relics of the (slightly dolomitic) limestone: quartz grains with glassy rims, shattered rests of the clay minerals (cristobalite!) and the above mentioned unfired fragments of these rocks.

There are visible structural differences between the plaster samples of the main nave and he lateral apsis of the church, what suppose, that the rough-casting of the internal walls were made in a few different phases.

4.4. Painting films

It is probable, that all walls (including stone elements) were painted both with lime milk and colored painting mixtures. Now, only the rest of these films can be observed, mainly in thin sections.

Thus, on the rock sample taken from the pointed arch of the sanctuary, three levels were identified: (i), fragmented films of a red material, hidden in cavities of the stone as small pockets, and covered by a thin black film; (ii) fine grained carbonate level (lime milk painting) and (iii) reddish film, which was protected by a 0.05–0.10 mm thick, amorphous, translucent, organic varnish film, probably egg-white (Plate 2, photo 6).

By the electron microprobe analyzes of the colored painting film, 2.1–4.1% iron was found (Fig. 3). It is known, that in medieval paintings, the main coloring substances were the natural (red, orange, yellow, brown) iron oxides and hydroxides.

Painting films were found on smut stone and brick pieces: the walls were repainted after an outbreak of fire. Painted (limed) films appear directly on the brick wall, under plaster levels: i.e. the church was put in service before the complete plastering of the walls, and the barren walls were temporally painted with lime milk.

5. WEATHERING PROCESSES ON THE BUILDING MATERIALS

5.1. Transformations on the stone material

Because the carbonatic composition and the porosity of these rocks, their sensibility for atmospheric, biologic and anthropogenic agents is relatively high. The changing of mineralogical composition leads to structural-textural modification in these rocks, and finally diminishes the mechanical resistance of them. In natural conditions, when a rock gets to the surface, i.e. they outcrop; their transformation under external factors began.

In the case of the carbonatic rocks, on one hand the karstic dissolution of the carbonate and on the other hand, the filling of pores and fissures with calcite and/or limonite, opal, sulfates, infilling of the clay minerals from the soil cover are the main transformations. The stone material which was extracted from its natural environment, and is carved and inserted in a building, went under to the same transformations, but with different intensity: slow

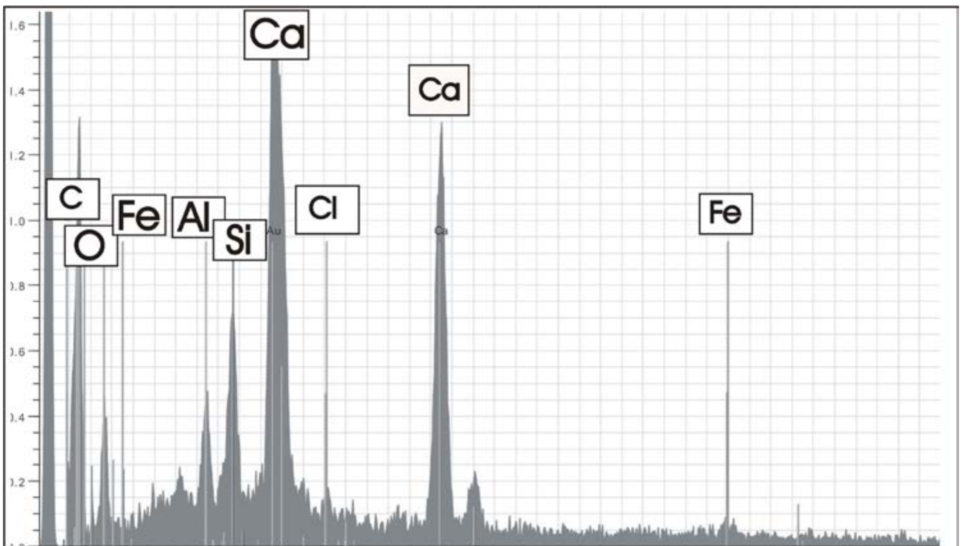

Figure 3. Electron microprobe spectrum of medieval painting film, from the pointed arch of the sanctuary

transformations in covered, protected sites and accelerated weathering in opened, discovered ones (because for the stones of the ruins the large, natural background as a buffer is missing).

The “geological” transformations of these rocks can be recognized, when the carved surface cuts them, i.e. the weathered, karstic surface, the well crystallized calcite (Plate 1, photo 1), limonite or clay-filled veins, voids or pores. On the contrary, if these ones are related to manmade surfaces that is sure, that the alteration was produced after the carving of the stone object and shows a secondary character.

The changes of the stone material can be caused by atmospheric (meteoric), biologic and anthropogenic factors. It is important to know, that these factors cannot be separated each another, they go together in space and time, finally causing the same effect: the destruction of the building object.

Meteoric factors. The weathering processes of the building become the main destructive factor both for stone and for other materials after the (last) outbreak of fire when the wood roof of the church burn down. Leaving the walls without protection, intense weathering processes began.

On the surface of the limestones, from a few mm to a few cm in depth, a part of the fine grained carbonate groundmass is dissolved. The loose, friable weathering crust leaves the stone piece, whipping the carved details as stria, pillar-heads, palmetto, acanthus, statuary pieces (Plate 2, photo 2.)

Biological factors. In our samples, in which the effects of meteoric factors as rainwater infiltration, diurnal variation of temperature and frost caused fracturing were recognized, together with the effects of biological weathering. The algal assimilation of CO_2 of limestone, the action of the root acids ad of the dejection of some insects, rodents and birds “mill” the rocks, or cover them with various secondary films: white and yellowish, grey and dark ones among which the microscopic and SEM analyzes evidenced calcium carbonate, gypsum, Ca-oxalate, phosphate and smut films. Note that the film includes dust particles and became dark grey. Thus, this dirty surface cannot be cleaned by whiff or wash away the impurities.

Among living creatures lichens play the leader role. In all humid nooks, shadowed corners, wind carved holes they are present and together with the pore water, the lichen colonies (Plate 2, photo 5) suck out the soluble components and pump a lot of organic acids into the rocks. Lichens prepare the way for more advanced plant species as mosses and grass pipes which still grow in the corners of the walls.

One of example of a typical combined meteoric and biologic weathering process can be seen in the lower section of the rosette (western wall). Here on the Sarmatian stone pieces, a lot of leaf like crust is detached. The frost caused fractures.

Anthropogenic factors. The first and decisive anthropogenic factor, which caused the destruction of the church (and of the surrounded settlement), was the fire, which happened probably during war times. On the stone material we find large surfaces with irregular network of fine fractures (Plate 1, photo 3) filled by dark material, what seem to be typical thermal contraction fissures.

The pollution of stones and other materials mainly by sulfates and smut has no doubt anthropogenic origin. If the acid rain, resulted from activity of farther industrial centers (e.g. Novi Sad, Timişoara, Szeged) reacts with carbonate, that result gypsum (Plate 1, photo 6), anhydrite, glauberite and other salts.

The smoke traffic, agricultural engines and coal based heating in the surrounded localities bring flying dark powder, enough for smudge the all of these walls. Apart from aesthetic damages in the porous or fissured stone pieces, the chemical reaction $CaCO_3 \rightarrow CaSO_4.2H_2O$ leads to 22% volume expansion. Thus, the sulfate weathering losses the rocks, mainly the porous ones.

5.2. The secondary effects in bricks

In the brick mass, the effects of fire, annual and diurnal temperature variation and of the frost, and of living beings as well were slighter, than in the case of the stone material, because the silicate composition of them resists better to chemical aggression and high porosity “brakes” tensional and compression forces. However, human beings were the most destructive factor: the achieve documents from 1863 talks about the systematic “exploitation” (i. e. the demolition for the own buildings) of these walls by inhabitants, “transporting with horsed carriages many tones of bricks and stones from these ruins” (Kollár et al., 2000).

The main secondary transformation of the bricks is happened in two phases: after the masonry and after the destruction of the roof.

Mortar and/or plaster lime infilling. The dry, often warm brick pieces fixed in the wall with limy mortar and covered with limy plaster has absorbed, together with the moisture, the calcium hydroxide, which were transformed in micritic calcite in pores, as (zoned) liners and void fillings.

Salt infilling in the pores. A few meter height to the floor, in pores of the wet bricks, small white points appear.

Plate 1

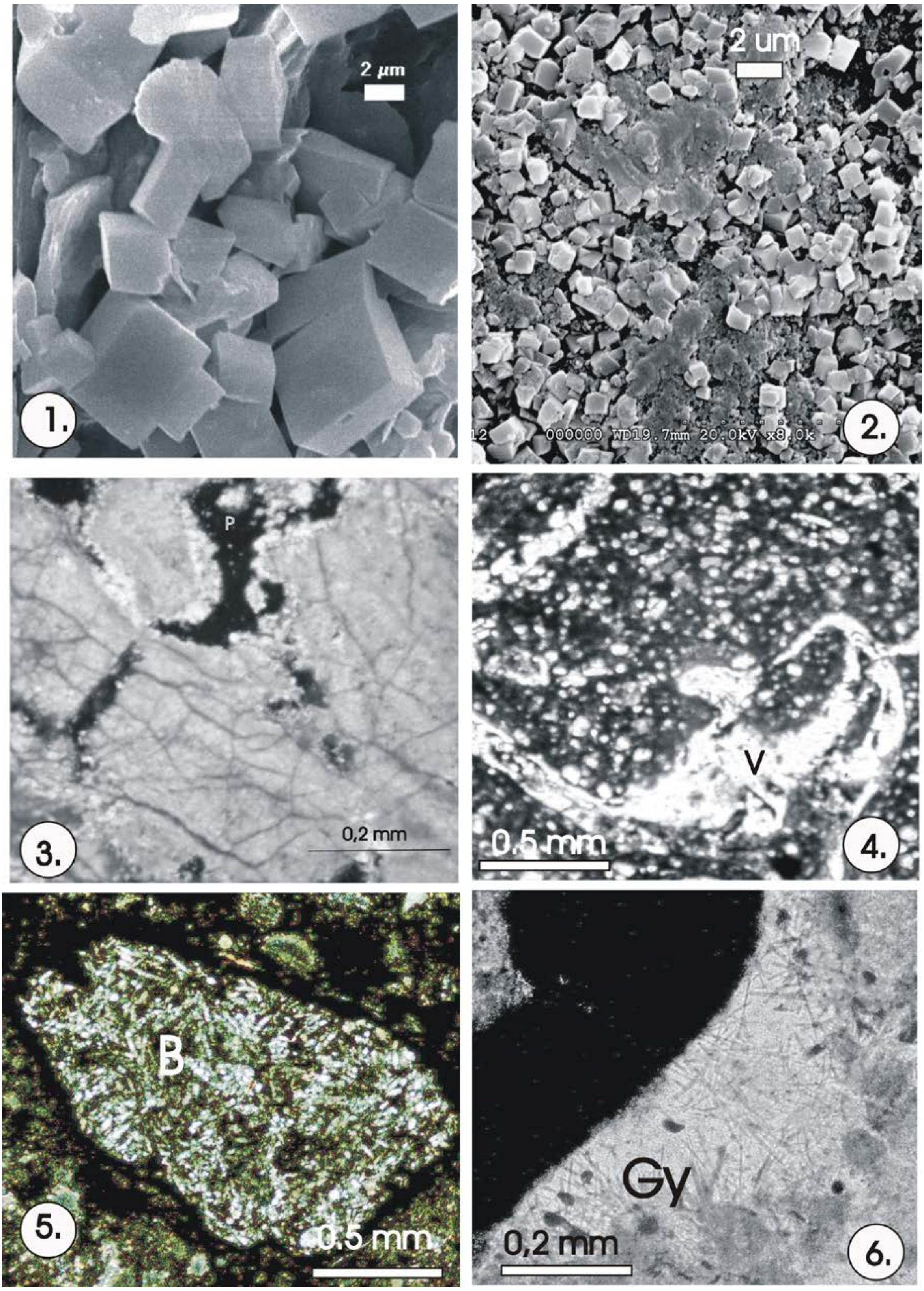

Photo 1. Euhedral calcite crystals from natural vein filling of Late Eocene limestone. SEM image
Photo 2. Euhedral and hemihedral calcite crystals and platty clay minerals in limy painting. SEM image
Photo 3. The fire fissure network cuts “geological” calcite liners of the pores of limestone. Thin section, + nichols
Photo 4. Pores in brick mass, burned vegetal fragments, probably wheat or hemp husks (V). Thin section, II nichols
Photo 5. Basalt grain (B) in the sandy fraction of the mortar. Thin section, + nichols
Photo 6. Gypsum needle like crystals (Gy) in the pore of the brick sample. Thin section, II nichols

Plate II

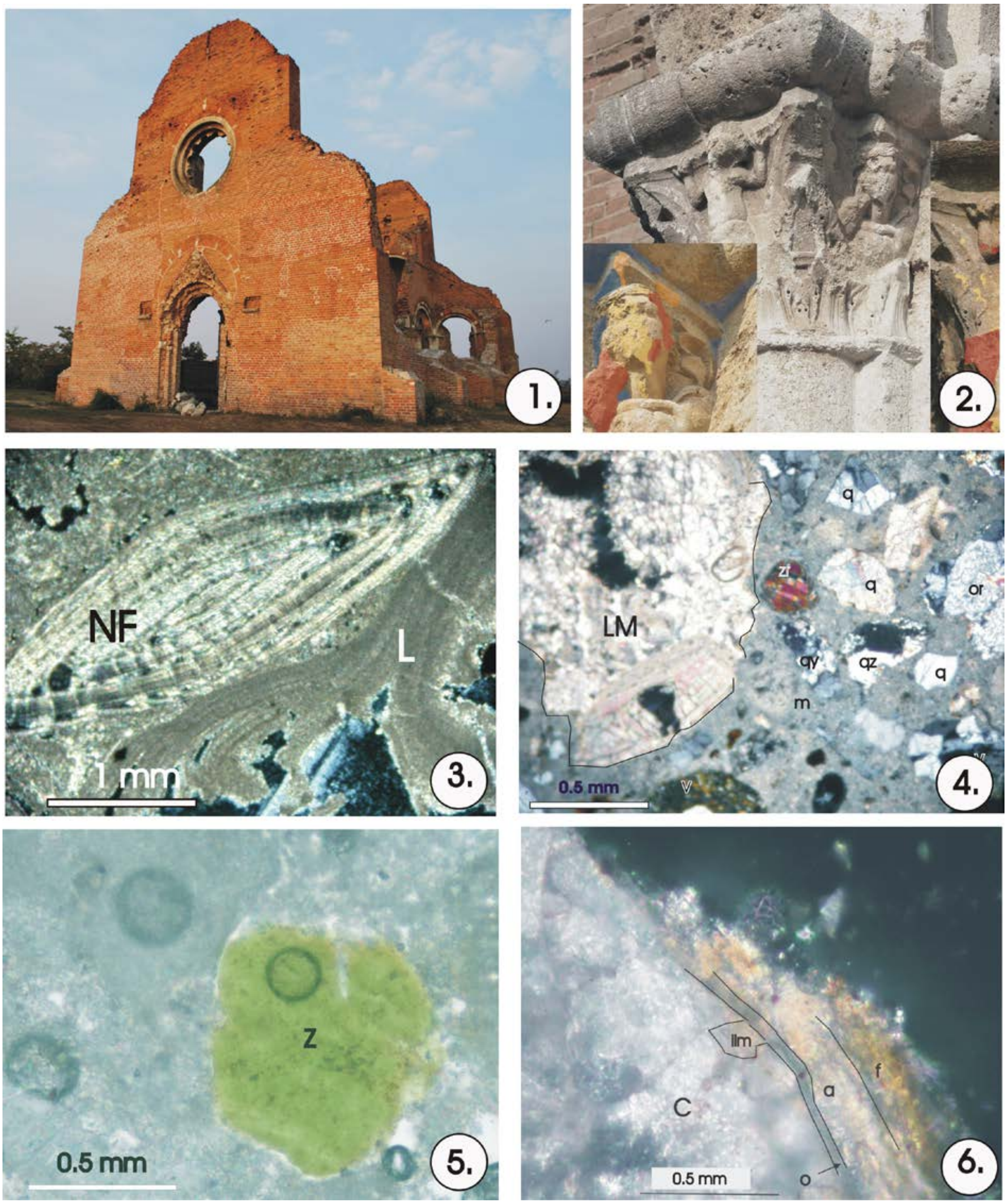

Photo 1. View of the Arač ruined church

Photo 2. The pile head with damaged carved works, Late Eocene limestone

Photo 3. *Nummulites* cf, *fabiani* PRÉVER (NF) and algal lumps (L) in bioclastic Late Eocene limestone sample. Thin section, + nichols

Photo 4. Mortar sample, with bioclastic Late Eocene limestone fragment (LM), quartz (q), orthoclase (or) and igneous rock grains (v) in fine grained, coalescent carbonatic groundmass. Thin section, + nichols

Photo 5. Lichen colony (Z) on limestone, with thin, translucent (probably Ca-oxlate) reaction rim. Thin section, II nichols

Photo 6. Stone piece from limestone, covered by three painting films: (1) the reddish, iron oxide bearing level (f) , covered by spots of grayish, isotrope vanish; (2) the lime painting, which covers the thin, black smut film (o) and (3) reddish pocket filling (lim) on a cavity of Priabonian limestone (c); it is probably a rest of the oldest painting film. Pointed arch of the sanctuary, thin section, + nichols

Table 3. Chemical composition of water soluble salt samples

Samples, mg/l	1	2	3	4	5	6	7
Al+3	2.05	1.51	1.85	2.25	2.36	2.01	2.83
Fe+2	0.92		0.38	1.08	0.52	1.44	0.32
Mg+2	0.00	11.17	25.81	19.30	34.60	12.96	26.68
Ca+2	66.10	44.43	36.18	40.12	67.47	63.48	41.18
Na+	4.48	7.76	10.87	9.16	0.00	0.00	10.28
K+	7.45	3.97	13.97	11,12	8.38	3.88	16.51
Cl	8.28	2.42	12.29	8.65	10.69	8.77	7.15
SO4-2	19.48	50.98	19.01	25.13	5.76	23.25	12.99
PO4-3	1.78	3.32		1.20	0.86	2.82	2,27

They represent the crystalline salt filling of some pores. The main components of these ones are Ca, Mg and Na chlorides and sulfates (see Table 3). The source of these salts is the groundwater, from where the solution rises into brick pores by the capillary pump and concentrates there. The crystallization of some salts with many water molecules in their composition presses the walls of the pores and breaks the ceramic mass, i.e. it crumbles away the brick.

5.3. The decay of the mortar and the plaster

More than stone and brick, mortar and plaster as highly porous, limy material were underline to meteoric and biologic destruction. The weathering of these materials began by the leaching of the carbonate binding of the sand particles and later, by their removal.

While the mortar binding was hidden and was protected between the brick pieces, the plaster surfaces were intensively eroded by wind and rainfalls. Note that on the most exposed Western wall the mortar between the bricks is deeply carved out, while on the protected internal sides, small plaster surfaces were conserved.

On the surface of the plaster, biological weathering effects as yellowish Ca-oxalate films and lichen colonies were observed. The electron microsonde sampling shows increased K, Ca and S contents on the surface. Apart from the mechanic concentration of lime milk during the floating of the rough-casting surface, these elements could be concentrated by biological activity and because of the anthropogenic sulfate pollution. Confirming X–ray analyzes (Table 2), in thin sections sphaeroidal gypsum aggregates and needle like gypsum crystals were observed.

5.4. The lack of paintings

Painting films disappear together with plaster surfaces. Now, these small spots suffer from the attacks of meteoric and biologic assault and effects of acid rain water as well. For restorers, it was a big, and may be the last chance to discover and to study the composition of these relics of medieval wall paintings.

6. CONCLUSIONS

Using the methods of applied geology, the natural and the man made building materials of an old, ruined church were studied.

After petrographical data, the stone material of the building was represented by three types of limestone, coming from Buda Mts., from the right side of the Danube on the territory of actual Budapest city. Triassic dolomite, Late Eocene limestone and Sarmatian oolitic limestone outcrop together only in this area.

The bricks, constituted the walls of the church, were made of local silty-clayey earth, as floodplain deposit of Old Tisa. In the mass of the brick samples, older brick debris, charcoal fragments, straw pipe and harle of hemp rests were found, too. Due to the transformation of sand grains and the presence of the rests of clay minerals, they were fired in artisan kilns at the temperature below 800°C.

The brick walls were bind with lime mortar and were covered by lime plaster. The mineralogy of the sand of these materials (mainly the metamorphic and igneous rock fragments) proves that it was transported from the alluvia of River Mureş. The lime for the mortar and for the plaster was obtained after carving from the fragments of the stone pieces. In some mortar samples, these rock fragments were recognized with characteristic bioclasts.

On the stone objects, on the bricks and on the plaster spots, a few films of painted surfaces were identified. The walls of the church were repeatedly painted, both with lime milk and with colored painting materials. The electron microsonde analysis put in evidence the presence of iron in these films, as the main coloring element.

The Arač church, built up in XIIIth century was brook down after the (last) outbreak of fire, when the wood roof was destroyed. Without any protection from wind, rain, frost, and by the attack of living beings, the stone pieces with fire caused fissures had weathered by the leaching of carbonate, the formation of organic products (e.g. Ca-oxalate) and calcium sulfate. The formation of the last mineral was the effect of acid rainfalls from industrial origin. Finally, from the stone pieces, the weathered crust leaved and the ornamental elements disappeared.

In the bricks, the main destructive factor was the crystallization of Ca, Mg and Na salts in the pores, when the salts came from the groundwater table by capillary ascension.

The same factors contributed to the loss of plaster level and the paintings both on the inner and on the outer side of the walls.

These analytical data can be useful for planning the restoration of this monument. Knowing the origin of stone material, the sand fraction of the binders and he bricks, the technology of the rough-casting and the painting, the specialists will be able to select the appropriate materials and technical tools for conserve this unique historical monument.

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