

PETROARCHAEOLOGICAL STUDY OF MEDIEVAL RUINS OF BZOVÍK FORTIFIED MONASTERY

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Abstract: The article represents the results of the complex petroarcheological study focused on the building material with respect to the restoration of the old fortified monastery Bzovík (Central Slovakia). The aim of the study was to determine the original building material and to suggest the best solutions of the building recovery. The petroarcheological study enabled to describe the present state of the used rocks, their resistance and several types of mortars. The aim of the study was determining the material of building. We found that the majority of the building stones are from the Neogene volcanics of the Štiavnica stratovolcano. Mainly effusive and extrusive activity of andesite volcanism. Distinguish the original and more new additional building elements, suggest suitable procedures and materials with respect to the sanitation of the building complex.

Keywords: building material, weathering, mortar, sanitation

1. INTRODUCTION

The fortified monastery in Bzovík (Figure 1), dedicated to St. Stephen the King, is one of the oldest church institutions in Slovakia. In the years 1127–1131, it was founded as a Benedictine abbey by Lampert. Between 1180 and 1181, the Benedictines were replaced by the Premonstratensians, who lived in the monastery until 1530. In the 15th century, a monastery building with a courtyard and a cloister in the Gothic style was added to the Romanesque twin-towered church. The original Romanesque structure of the church and monastery was only partially destroyed by the Gothic modification (Borovszky, 1906).

In 1513, the monastery was expelled by Zigmund Balassa. He subsequently rebuilt the monastery into a fortress. The complex burned down in the 17th century. Subsequently, it was rebuilt in the Baroque style. In this period, the monastery comes back into the ownership of the church. The Ostrihom Chapter sold the fortress in 1908. Since then, the fortress has been abandoned; it was heavily damaged during the Second World War. Only ruins have been preserved from the area of the former monastery, which gives an idea of the scale and layout of the buildings. Of the former beautiful buildings of the monastery, only one Gothic sacristy stands today, later changed to a chapel, the others have been demolished (Maliniak et al., 2018).



Figure 1. The Bzovík fortified cloister

During both world wars, the complex was significantly damaged and gradually dismantled as building material. The state has owned it since 1952. Subsequently, in 1964, the monastery was registered as a cultural monument (Lászlóová, 2003).

Petrographical and mineralogical investigation of various building material and artifacts by microscopy is a often auxiliary technique that has been used in the service of archaeology. The first substantial study of this field of interest was published by Shepard (1936). This type of study was successfully applied in numerous countries and for study of materials from different ages as a necessary basis for the successful evaluation of the studied structures and objects, ascertaining their origin, or

for obtaining the data necessary for their rescue and restoration (Childs, 1989; Herz & Garisson, 1998; Stoltman, 2001; Hacle, 2007; Garrison, 2016).

The aim of the work was to study the building material from which the individual parts of the complex were built, to determine the state of its resistance or damages caused by the centuries and to propose suitable materials that will enable the renovation of the fortified monastery complex to be carried out in the most appropriate way.

2. MATERIAL AND METHODS

For the study of the artifacts (rocks and mortar), we used thin section. Microscopy of individual minerals consisted of a detailed microscopic study of the optical properties of minerals on a NIKON ECLIPSE LV 100 POL polarizing microscope, in polarized transmitted light. Microphotographs were taken with a NIKON DS-R11 camera.

The mortar was studied also by X-ray diffraction analysis using Bruker D8 ADVANCE DAVINCI. DESIGN diffractometer in connection with Sol-X SDD detector (measurement conditions: CuK α radiation, 40 kV, 40 mA).

3. THE BUILDING MATERIAL

The monastery is situated in the Central Slovakian Neogene volcanic zone, which consists of the products of the Štiavnica stratovolcano and, on the edges of the area, the Javorina stratovolcano.

The development of the Štiavnica stratovolcano took place in several stages between Badenian-Sarmatian and Panonian times (Konečný et al., 1998a). The main structural unit is the Sebechleby formation. The Sebechleby formation is a volcano-sedimentary complex of Middle Badenian age (16 Ma – Repčok 1981).

The dominant rocks represent the product of explosive-effusive and extrusive activity of andesite volcanism: epiclastic facies (breccias, conglomerates, sandstones), lava flow, and pyroclastics (Konečný et al., 1998b; Lexa et al., 2010).

The ruins of the fortified monastery are built on a hill, in an area that is not threatened by earthquakes, landslides, floods or other natural disasters. In the past, only two factors had a significant effect on the building: a) anthropic activity (destruction of buildings as a result of fighting and use of building material from an abandoned building for construction work in the vicinity) and b) weathering of stone building elements.

The monastery complex was built from different local materials (Figure 2). Parts of the complex (especially the fortifications) are built of andesite, which is in good condition even after centuries. Formation is a



Figure 2. The wall of the cloister: andesites (A) and pyroclastic material (P)



Fig. 3a)



Figure 3 b)

Figure 3. a. The sandstone lining of the Gothic window in wall of the chapel; b. the sandstone lining of the niche in the wall of the fortification

volcano-sedimentary complex of Middle Badenian age (16 Ma – Repčok 1981). The main rocks are the product of explosive-effusive and extrusive activity of andesite volcanism: epiclastic facies (breccias, conglomerates, sandstones), lava flow, and pyroclastics (Konečný et al. 1998b; Lexa et al., 2010).

This type of masonry does not require, except for local strengthening of loosened mortar, more serious reconstruction interventions. Gray sandstones (Figure 3a) are relatively resistant to weathering. Yellow sandstones are less resistant (Figure 3b).

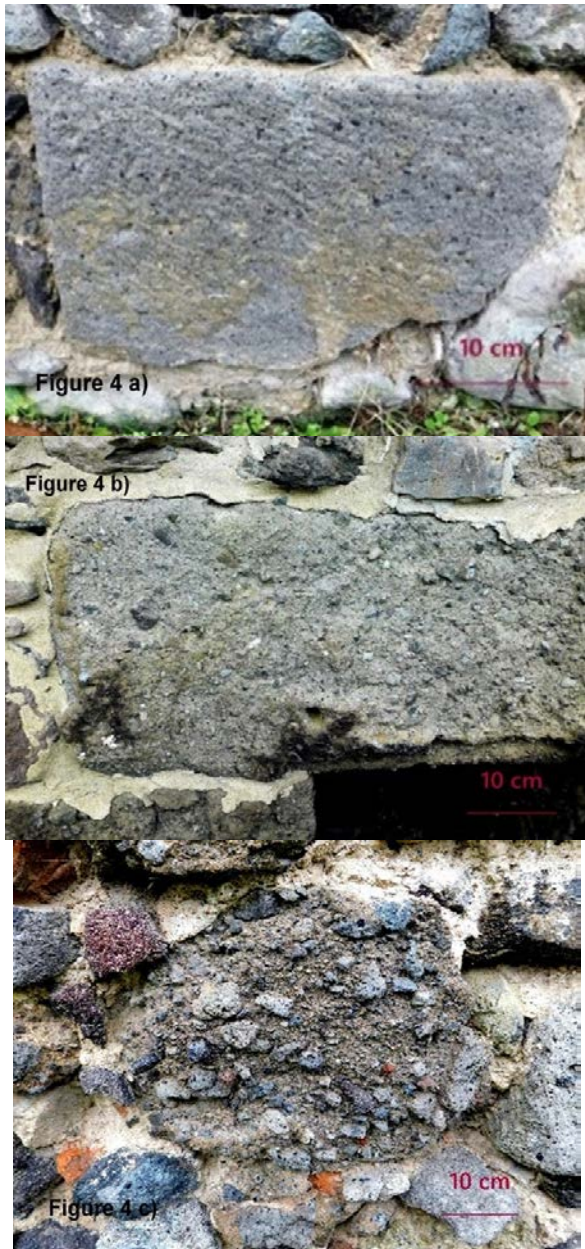


Figure 4. Types of pyroclastic rocks: a) fine-grained, b) coarse-grained, c) conglomerates

Coarse-grained pyroclastic rocks weather the fastest (Figure 4a). Parts of masonry built from this type of stone are heavily damaged. Finer-grained varieties show a significantly higher degree of resistance to

weathering processes (Figure 4b,c).



Figure 5. Details of the rest of a wall of the Cistercian Abbey built from carved pyroclastic rocks



Figure 6. The fortification is built by andesitic rocks

Most stones are not chiselled, but some little portions of the stones were carved, e.g. details of linings (Figure 5) or several walls of the monastery. The most weathered material is represented by coarse-grained pyroclastic rocks (Figure 4c) and the most resistant are the andesite rocks (Figure 6).

The results of the microscope petrological study of the building material are presented on figures 7 – 14.

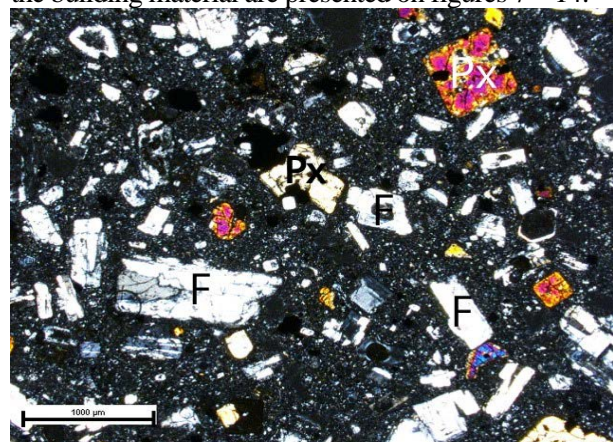


Figure 7. Altered dacite, vitreous matrix is strongly devitrificated. In the matrix are visible phenocrysts of feldspars - F and pyroxenes - Px (crossed polars).

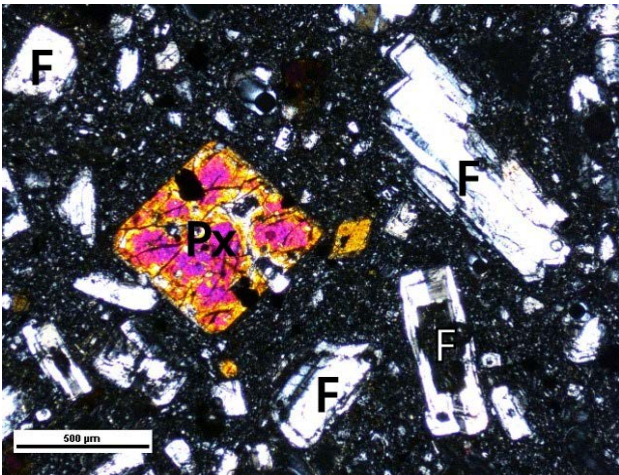


Figure 8. Detail of feldspars (F) and pyroxene (Px) phenocrysts (crossed polars) in andesite

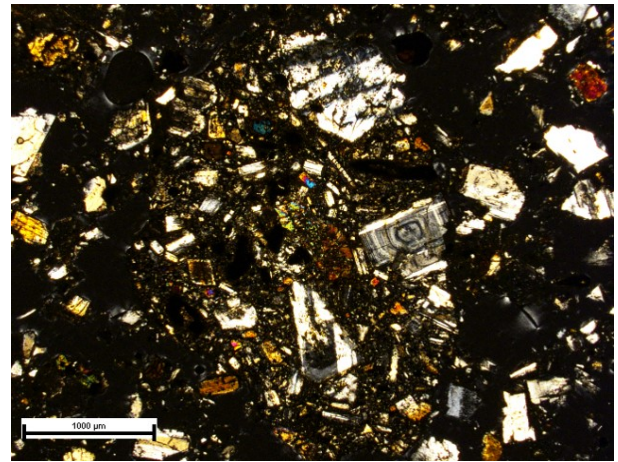


Figure 9. Ignimbrite (caked fragments) of andesitic rocks and of fine-grained ash. In fragments are visible zonal feldspars and pyroxenes (crossed polars)

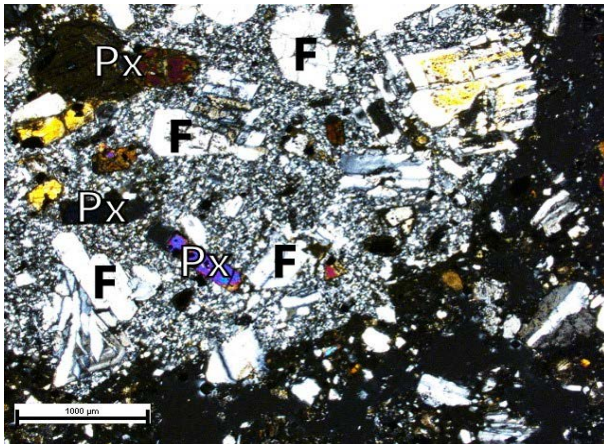


Figure 10. Ignimbrite - caked fragments of dacitic rocks and of fine-grained ash. In fragments are visible zonal feldspars - F and pyroxenes - Px (crossed polars).

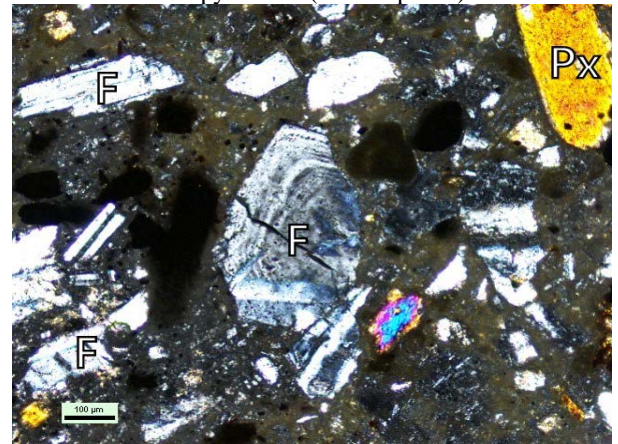


Figure 11 a) Fragments of feldspars (F) and pyroxenes (Px) in devitrificated matrix (crossed polars); b) Rhyolitic tuf with prevailing vitreous matrix; detail of feldspar fragments (crossed polars).

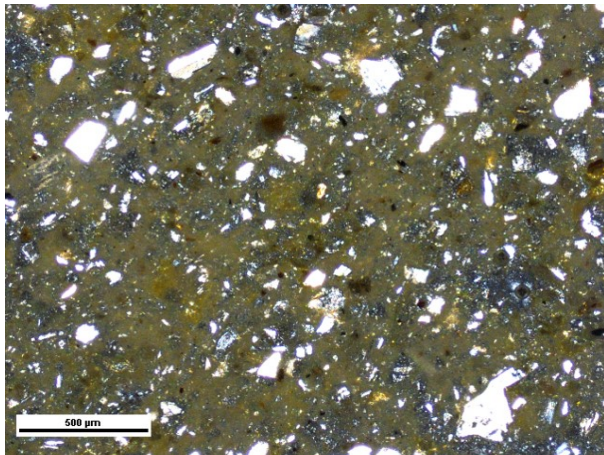


Figure 12. Rhyolitic tuff with prevailing vitreous matrix (crossed polars)

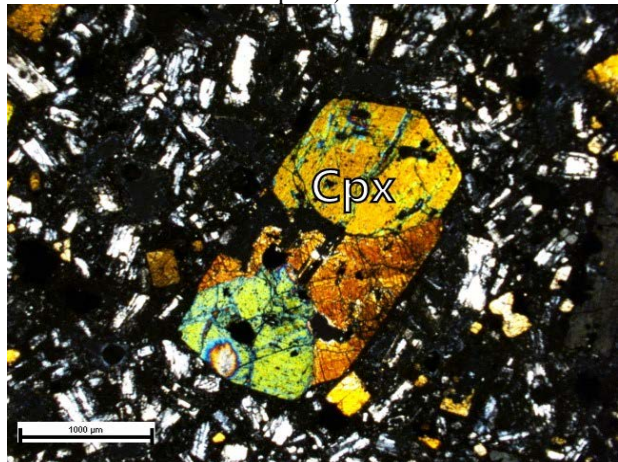


Figure 13 Phenocryst of zonal clinopyroxene (Cpx) in andesite with nice example of hourglass texture (crossed polars).

4. THE CHANGES OF PLASTERS DURING THE CENTURIES

The oldest Medieval mortar is of a sand and slaked lime – $\text{Ca}(\text{OH})_2$ composition (Figure 15). The lime from various lime factories had different quality. A

very nice example of such a mortar is the mortar sample presented in Figure 16. The substantial part of the sample consists of quartz, feldspar (basic plagioclase andesine), and calcite from local sources (derived from surrounding volcanic rocks). Less important admixtures are represented by hornblende (amphibole) and of various

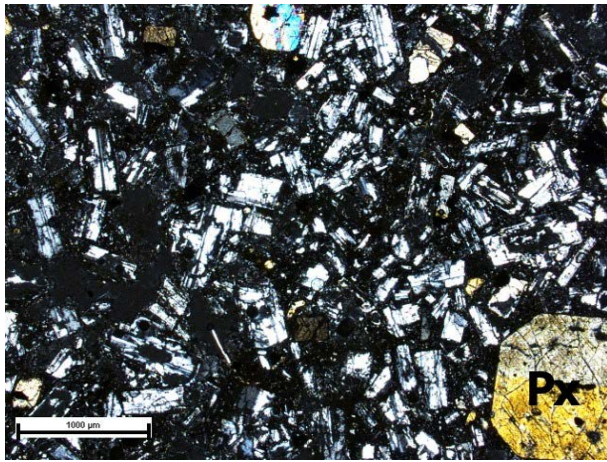


Figure 14. Ophitic texture of andesite with pyroxene phenocryst (Px) (crossed polars)

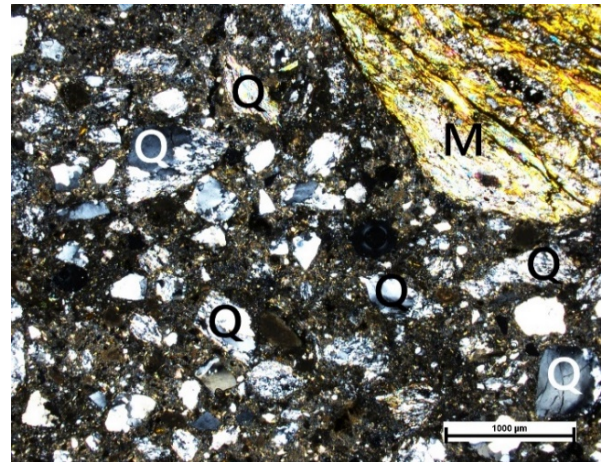


Figure 16 Mortar sample containing fine-grained quartz grains (Q) and mica (M) (crossed polars)

phyllosilicates (chlorite, montmorillonite and muscovite). Also accessory presence of gypsum was proved (Figure 15). It could be formed by secondary processes (from sulfides) or could be added to the mixture with the intent to accelerate the duration of the mortar.

The microscopic study of the younger type of mortar (maybe from 19th century) shows that it consists of fine-grained (the size of the grains is approximately 0.5 mm) sharp-shaped chips of quartz and fragments both of sedimentary and metamorphic rocks, eventually from larger (several mm in size) fragments of metamorphic rocks (phyllites and schists) or mica-sandstones (Figure 17).

The next mortar type is different. It contains a predominantly aphanitic matrix with the addition of fragmental material (Figure 18). It is possible to identify zonal feldspars and clinopyroxenes in volcanic rocks. The rolled fragments indicate that they were transported from some faraway locality. Fragments of sedimentary rocks are rare.

The mortar from the second half of the 20th century consists of a fine-grained matrix with sharp-shaped grains of undulatory quartz (Figure 19). Besides quartz, there are greater grains of feldspar and fragments of volcanic rocks. Great, partly rounded clasts of fine-grained quartz and volcanites are rarely visible. The

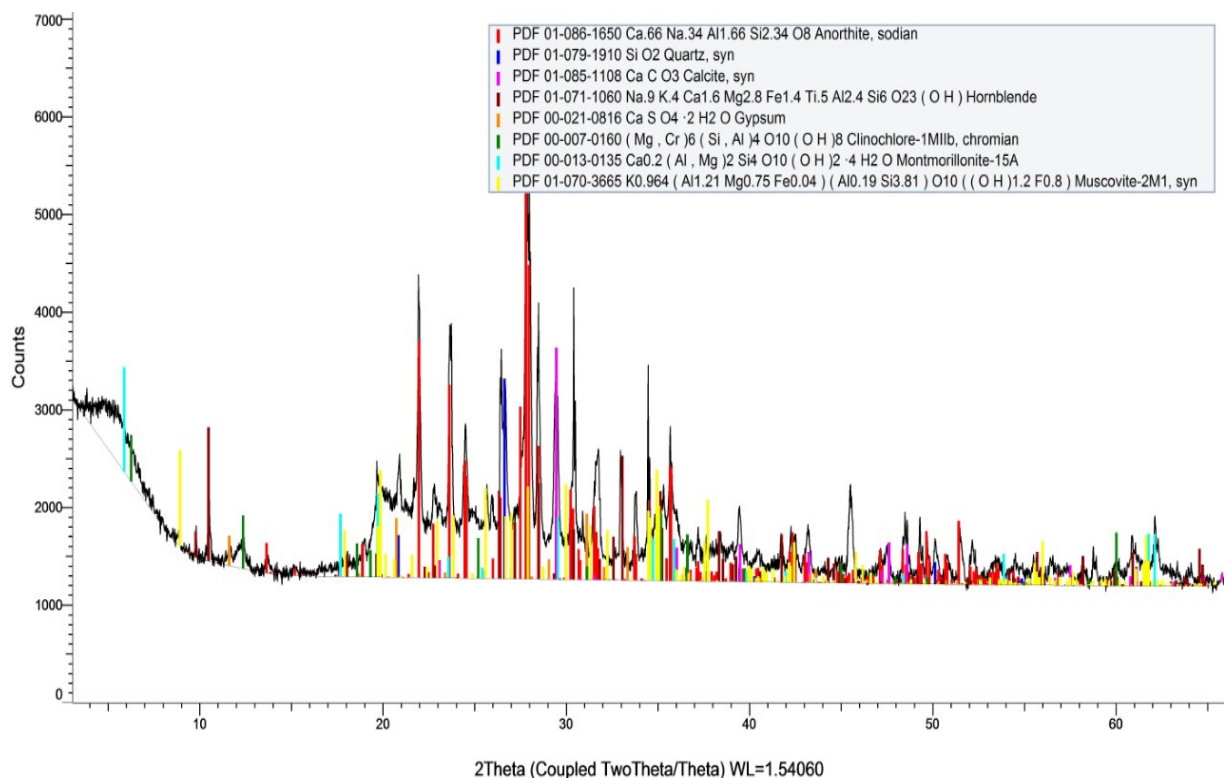


Figure 15. X-ray diffractogram of the oldest Medieval mortar.

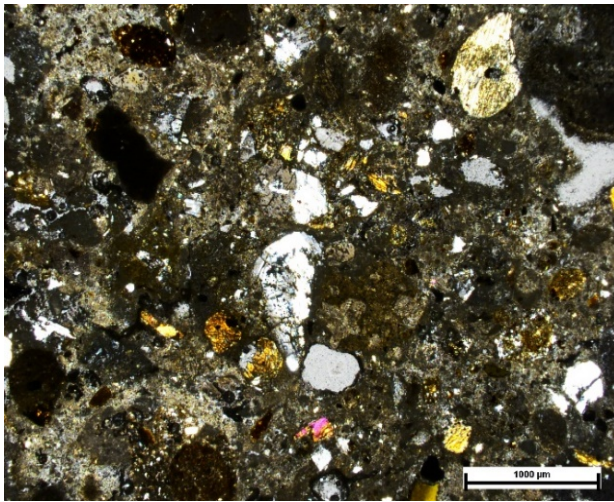


Figure 17. Aphanitic rock-material in the mortar (crossed polars).

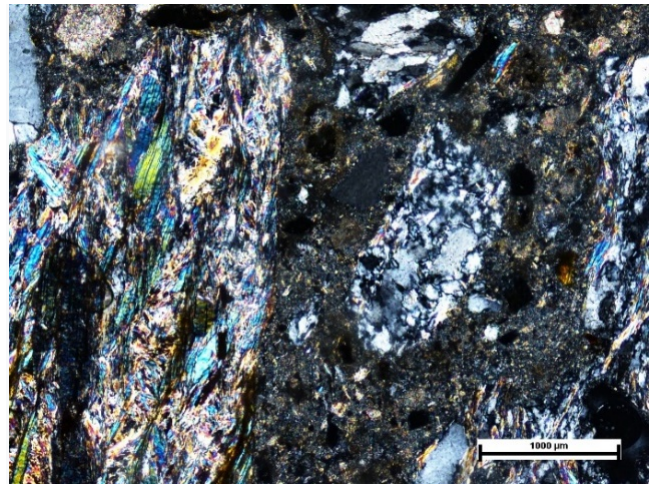


Figure 18. Mortar from the second half of the 20th century: fine-grained grains of quartz and volcanogenic rocks.

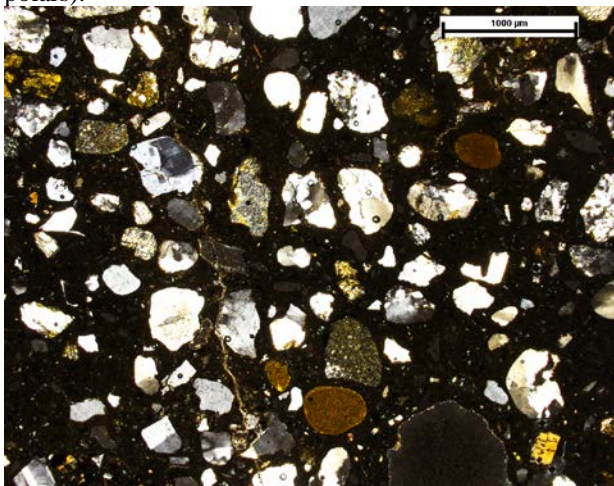


Figure 19. Fine-grained matrix of mortar with sharp grains of undulatory quartz (crossed polars).

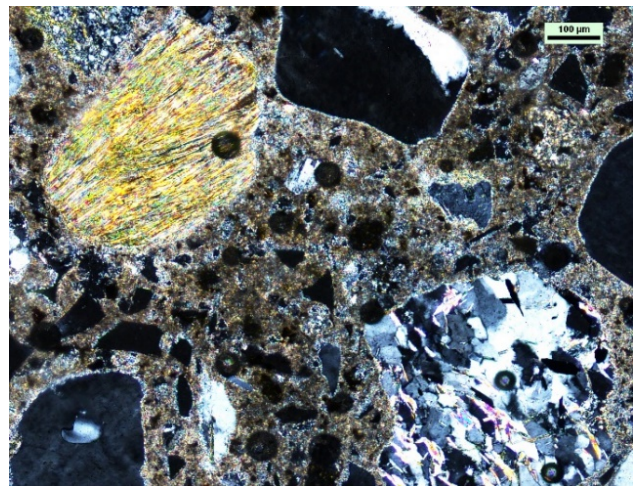


Figure 20. Sharp feldspar and gneiss fragments with a fragment of mica (yellow; crossed polars).

predominant part of the fragments show that the origin of the material descends from local neovolcanites.

The mortar in other samples from the same time has approximately the same character. The material consists of a fine-grained matrix with sharp grains of undulatory quartz (Figure 20). The rate of crispness in the material is about 50:50. Besides quartz, there are also greater grains of sharp feldspar and gneiss fragments and locally also by mica-sandstones (Figure 21).

The X-ray diffraction analysis shows that in the mortar sample presented in Figure 21 there is dominant quartz, plagioclase (mainly albite), and calcite portlandite - a calcite in mixture with lime and portlandite. As accessory minerals, there are also hornblende (amphibole) and various phyllosilicates (chlorite and muscovite). The sand is relatively well culled and contains more or less only quartz. The presence of apatite grains, which are because of their high weight usually accumulated in water sediments, indicate that it is most probably a river-sand. Gypsum is probably of the same origin as in the mortar from the above mentioned Medieval sample.

Since the end of the 19th century was used lime-cement mortar. Its component can be also portland cement which influence to mortar better mechanic properties.

5. DISCUSSION

Geological and mineralogical investigation of monuments with respect to their restoration is relatively common (e.g. Bruno et al., 1968; Chiari, 2000; Andráš, 2004; Tóth et al., 2014).

For a suitable recovery of the building, it is necessary to know the character of the building material, e.g., of the bricks or rocks, bricks, wood components and also get information about the type and composition of mortar, plaster coating, external rendering, etc. and know, (Mikhailovskij, 2011).

The importance of the mechanical erosive influence of wind and water is well known. Among the next factors that are necessary to mention, e.g., temperature changes, which have a role not only in water

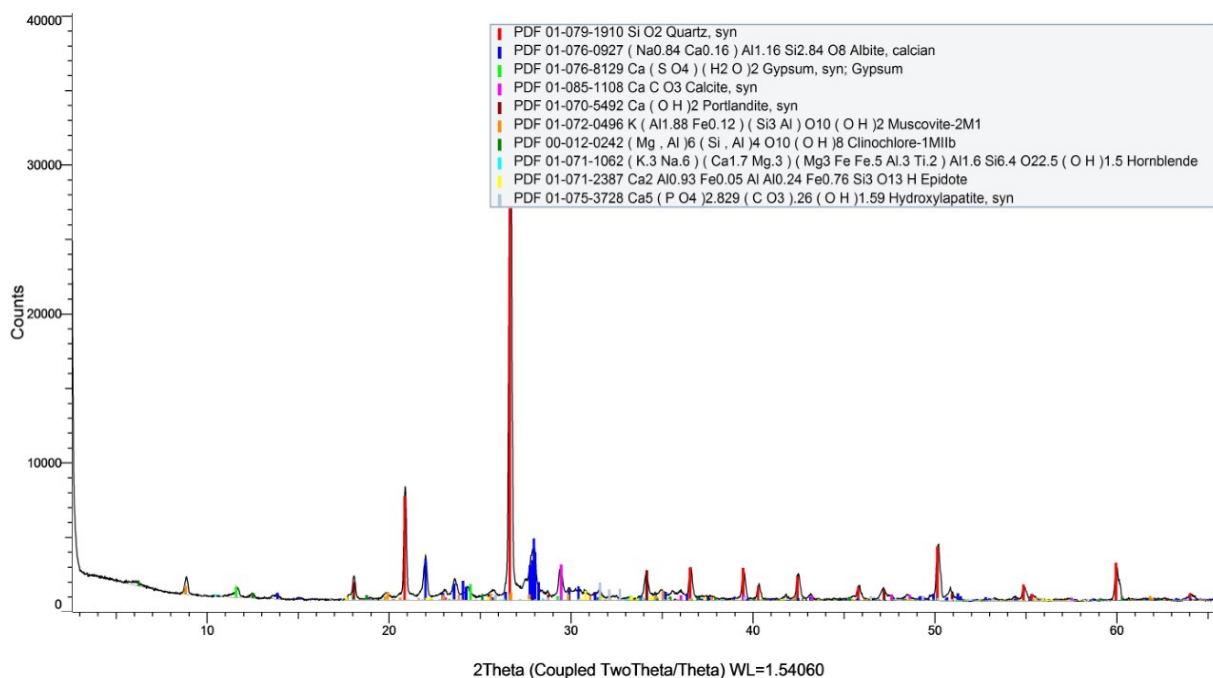


Figure 21 X-ray diffractogram of the mortar from 20th century

phase changes but also in salt-induced damage. During the winter, frost can cause great damage: both to itself and as a consequence of water freezing. The ice is able to destroy the building material because of the increase in the internal pressure as the water volume increases during freezing by 9%. Frost damage can occur as cracks, stone splinters, and swelling of the building material. The cumulative effect of all these factors is able to cause erosion or progressive fatigue of material (Heckroodt, 2002; Delgado et al., 2016).

The next important physical factor is the fire. Degradation of building materials may have various causes. It can be damaged also by chemical agents. The most common reasons for chemically affected damages are the consequences of water, acid rain (acidification), carbonatation, salinization, sulfate attack and oxidation (Přikryl & Smith, 2007; Drdácý et al., 2015).

The building material of the monastery, which was built from different materials: sandstone, rhyolite, tuffs (pyroclastic rocks), and andesite, is more susceptible to weathering (Figure 2). Gray sandstones (Figure 3a) are relatively resistant to weathering. Yellow sandstones are somewhat less resistant to weathering (Figure 3b). These can be preserved using normal restoration procedures. Coarse-grained pyroclastic rocks weather the fastest (Figure 4 b, c). Parts of masonry built from this type of stone are irreparably damaged. Without interfering with the nature of the masonry, these pieces of stone can be replaced with the same type of rock, which is finer-grained and shows a significantly higher degree of resistance to weathering processes (Figure 4 a, 5).

Parts of the complex (especially the fortifications) are built of andesite, which is in good condition even after

centuries. This type of masonry does not require, except for local strengthening of loosened mortar, more serious reconstruction interventions. It is most suitable for reconstruction work to use an original type of material, consisting of lime and sand, for plastering and for binding stone parts of the masonry, which is functional even after centuries and which has demonstrated an extremely good ability to bond with the masonry.

The origin of the rock material in the Medieval mortar is from local volcanogenic sources. We found that the majority of the building stones are from the Neogene volcanics of the Štiavnica stratovolcano. The main source was the effusive and extrusive activity of andesite volcanism. The material of the younger mortar, which was used probably in the 19th century, seems to be derived from metamorphic or magmatic rocks from some far unknown locality. In the youngest mortar from the second half of 20th century was used again local material from neovolcanic area.

6. CONCLUSION

Scientific knowledge, technological in-novation and the development of new materials will provide useful tools for stakeholders to apply effective strategies and to plan on time proper preventive conservation measurements to the improve the condition of the ruins and enjoyment of cultural heritage, not forgetting an integrated and holistic approach to protecting (not only) cultural heritage.

First of all, it is necessary to remove inappropriate construction interventions in the original complex (remove brick partitions in bastions, reinforced concrete terraces and staircases). It is also possible to remove the

rubble that covers a significant part of the buildings from the monastery grounds. Some damaged details can be sensitively restored or their original meaning can be indicated by partial reconstruction.

It is appropriate to use the original materials for the repair of the buildings, but select for this work the most resistant types of the rocks (e. g. not coarse grained but fine-grained pyroclastic rocks) and the original composition of mortars.

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