THE POSSIBILITIES TO USE THE TRAVERTINE AND ONYX – GULABOVA CAVE, BESISTE VILLAGE (WESTERN MACEDONIA) AS AN ARCHITECTURAL STONE

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Abstract
The travertine and the onyx from Gulabova cave, Besiste village, in western Macedonia have been examined in order to determine the possibility to use them as architectural stone. The analyses and the laboratory research were performed on samples of travertine and onyx. The samples were taken from the surface parts. The results from their physical mechanical examinations have shown that the rock mass itself satisfies the requirements to be used as an architectural stone according to the state standards of Macedonia. The quality of the stone is higher in the deeper parts of the field where the external influences have a very small effect. This stone has highly decorative features but it also has fine grained structure which is a positive effect for the technical characteristics and the subjection for processing and production.

Key words: travertine, onyx, Gulabova cave, architectural stone, mineral-petrographic content, structural-textural characteristics, physical-mechanical characteristics.

INTRODUCTION

The area of research for travertine and onyx from Gulabova cave, Besiste village which is located in the south-western mountainside of Kozjak mountain in Mariovo. The location itself is around 3km. away from the Besiste village and around 40 km. from Prilep.

The field of research of travertine and onyx is part of the Neogene period surrounded by distinguished hill and mountain forms, with the most significant ones being Sv. Pantelej (1344 m.), Perun (1730 m.), Gurov kamen (1566 m.), Cucul (1220 m.), Baltava Cuka etc. The main water flow of this region is Crna River which is the biggest right confluence of the river Vardar. The Crna River drains the waters from the biggest part of the region, and the greatest confluents are the following rivers: Eleska reka, Graeska reka, Konjarka, Trnovicica, Gradeska, Blasnica, Belica, Besiska reka, Stravinska reka, Satoka, Buturica, etc.

The first geological information of the field is related with the first geological research of the Pelagon area, done in the beginning of the last century. Cvijik (1906) wrote about the crystal–like rocks with granite core of Precamric age. Kosmat (1924) made the first devision of the field in units. Marik (1949) did a research on the rocks between Bakarno Gumno – Alinci and Vespec. Ilik (1953) did a research on the pegamatite and the useful minerals related to them in the area of Babuna and the northern part of Selecka mountain. Kolman (1951) and Izmajlov (1951) made a geological map of the field between the villages Mrzen and Galiste in the valley of Crna reka river.

Barik (1956) did the most detailed mineral examination of the disten from the Selecka mountain. Stojanov performed a research (1958 и 1974) of the disten from Selecka mountain. Mayer (1960) in the area south from the village Bonce, gave a description of metagabbro. Protik (1963) in the south western part of Selecka mountain selected schist with smaller crystality. Teofilovik (1966) made his research in the southern part of the Pelagon. With the process of making the geological map of SFRY, the authors of the leaves Vitoliste and Kajmakcalam in a proportion of 1:100 000 (Dumurdzanov, Hristov, Pavlovski and Ivanova 1976), made a detailed elaboration of the leaf content of the rocks in the leaves Vitoliste and Kajmakcalan, describing the composition of the rocks considered and the presence of the onyx in the upper parts of the travertine rocks.

The latest data concerning the geological composition, the petrographic-mineral and physical-mechanical characteristics of the onyx can be found in the professional documentation of the company 'Maksoniks'.

APPLIED RESEARCH METHODS

The mineral-petrographic examination were done by the Faculty of natural and technical sciences in Stip by the authors of this paper, while the chemical content of the granodiorite is determined by the chemical laboratory in Zelezara in Skopje.

The examination of the physical-mechanical characteristics is made in the laboratory of the Faculty for Civil Engineering in Skopje. All examinations were performed during 2010. Because of the fact that the rock masses are not well disposed, the samples were taken from the surface of the field, and as a consequence of this, there are some cracks which are a result of the increased atmospheric influence. However, the examination of the samples has shown relevant values of the physical-mechanical characteristics. It is beyond any doubt that samples from greater depths would give much better results.

GEOLOGICAL CHARACTERISTICS

In the geological constitution of the locality Gulabova cave the presence of the striped muscovite-biotite and striped muscovite gneiss are mostly present, together with massive medium to large grained granodiorite, volcanic sediment products, quartzlatite agglomerate and tufa and carbonate-tufa products.

The greatest presence is of volcanic sediment products and carbonate-tufa products (Fig. 1)

Volcanic sediment products

The volcanic sedimented products in slightly lesser masses are present in Besiste (Figure 1). During the intensive volcanic activity at the Kozuv volcanism, great quantities of volcanic material (volcanic sand, dust, ashes, volcanic lapilli, bombs and blocks of volcanic rocks – quartzlatite, andesite, tufa) have been erupted in this part of the field.

In this volcanic material in the Pliocene-quarter lake reservoir, mostly stratified figures of volcanic agglomerate, breccias, pyroclastics, tuffs, tuffites, etc., have been formed, in which stratified figures with various thickness dusty weakly-tied sands, clay and sandbanks, are embodied. There are often fragments and blocks of volcanic rocks in these layers.

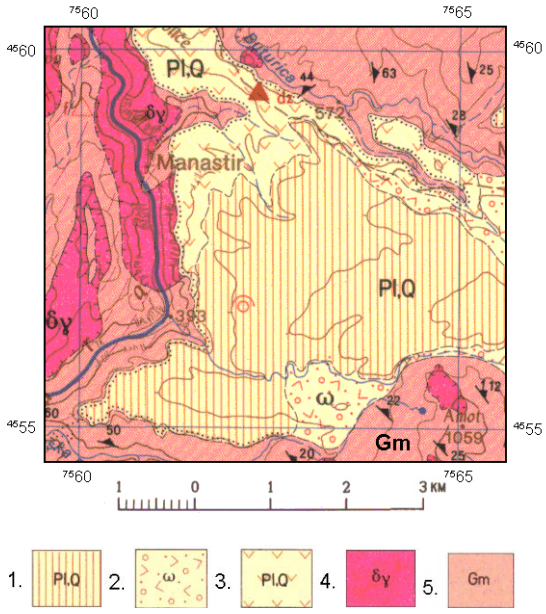

Figure 1. Geological map of the locality Gulabova cave 1. travertine and onyx 2. carbonate-tuffaceous products 3. volcanic sediment products 4. granodiorite 5. gneisses

Carbonate-tuffaceous products

The carbonate- tuffaceous products have been found in the centre of the researched area (Picture 1). These products are represented by stratified and flat tufa, tufa limestone, travertine and onyx. These creations are mostly layered by interstratified sandbanks, dusty sands and grinded tufa. The tufa, the tufa limestone, the travertine and the marble onyx are mostly brown and grey-yellowish massive and quite compact but in certain intervals they can be porous and with cavities (Figure 2). The travertine is featured with fine-grained composition, compact, massive and fairly porous texture. There can rarely be found cracks with 2mm. length.

The calcium carbonate rock is formed of calcite which is mostly found in cryptocrystal form. The calcite mass often produces irregular oolitic forms, round and oval with zoned structure of calcite mass. The oolitic forms on the parts of the edges are framed with stronger limonization. The cracks are not frequent and are fairly small. In the cracks as well as in the irregular forms, the rock is filled with recrystallized calcite – micro crystalized and pure (Figure 3).

Figure 2. Stratified, porous and cracked light grey travertine

Figure 3. Cavity in massive travertine filled with recrystilized calcite

Figure 4. Thin layers of brownish-yellow onyx (1) and massive brownish-grey travertine

The onyx is brownish-yellow color in various nuances (Figure 4) and it can be found in the more shallow levels (up to 30 meters), while the limestone tufa is very compact and firm and it can be found in the deeper levels of these series. It has compact, massive and slightly distinguished striped texture. The calcite crystals that constitute the onyx are thin, long and straw-like forms, crystallized diagonally on stratification. It is possible that the calcite is presented by aragonite, as a polymorphic modification of calcite. In most of the examined holes, presence of vulcanite in the tufa series have been found, which points to the fact that there has been sedimentation of both carbonate and volcano agglomeration.

PETROGRAPHIC – MINERAL CHARACTERISTICS

Represented samples from Gulabova cave have been selected for the petrographic – mineral examinations. The petrographic slides were made, viewed microscopically with a polarized microscope with transmitting light brand Leitz, Wetzlar Germani. The petrographic – mineral examinations were done at the Faculty of natural and technical sciences at the Institute for geology by the author of the paper.

The travertine has light beige color with rare irregular forms colored light grey. They are characterized with fine grained composition, compact, massive and fairly hollow texture. Cracks are rarely found, small with length of 2mm.

The rock is made of calcite, which is basically in cryptocrystal form and structure. The calcite structure often makes irregular oolitic forms, round and oval around the edging frame of the calcite structure. (Figure 5a, 5b). The rock is filled with recrystallized calcite – microcrystal and pure. The granulation of the calcite in these forms is around 50μ. The irregular forms are more rarely found, gloomy brownish i.e. strongly colored with limonized oxide. As additional minerals there are some quartz grains and rarely lamina of mica that can be seen, and it can also be said that there are only residues.

Figure 5a. Microphoto of the sample GP-110x (N-)

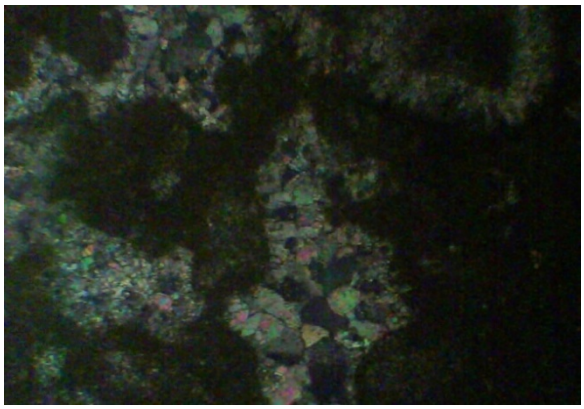

Figure 5b. Microphoto of the sample GP-110x(N+)

The marble onyx is characterized with large crystalized structure, compact, massive and with slightly distinguished striped texture. The calcite crystals are thin, long and straw-like forms, crystallized diagonally on stratification. It has light brownish and brown-yellowish color, with nuances of lighter and darker spots which gives the rock a better appearance. It is constituted of calcite, which has large crystal structure. Those are long straw-like crystals of calcite with radiant rayed darkening (Figure 6a, 6b). Separate parts of the calcite are strongly colored with limonized oxide, which point the striped structure of the rock. This is a result of the genetic background of the onyx, i.e. the inflow of tinctures of limonized oxide.

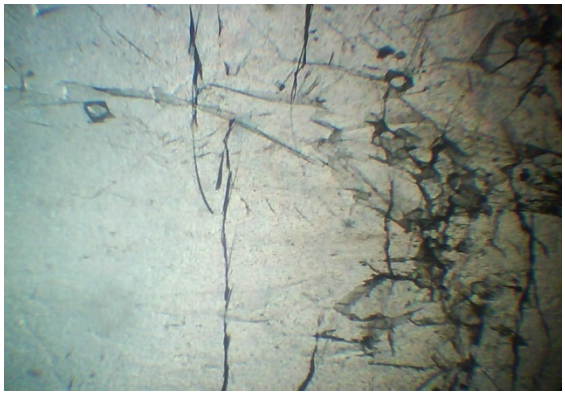

Figure 6a. Micro photo of the sample GP-4 10x (N-)

Not so often, visible diagonal transections of calcite can be seen in partly rhomboid crystals. It is possible that the calcite is presented by aragonite, as a polymorphic modification of calcite. Very rarely there can be crystals which resemble the dolomite – ancerite.

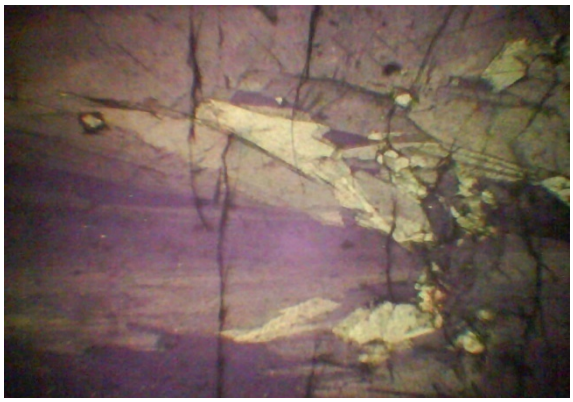

Figure 6b. Micro photo of the sample GP-4 10x(N+)

CHEMICAL EXAMINATIONS

The chemical characteristics of the travertine and the onyx from the locality Gulabova cave, represent an addition in the process of expanding the findings of this type of rocks in the territory of the Republic of Macedonia. Considering the composition, the structural-tectonic features, the color and the manner of their appearing, these rocks are clearly different from the surrounding ones.

The samples GP-1 and GP-2 are travertine, with quite pure calcite composition. According to the chemical analysis of the samples, the participation of MgO is between 1,64 - 2,70 % (Table 1). The analyzed sample of onyx is also characterized with quite clear calcite composition where the content of the analyzed elements are quite low with the exception of CaO.

Table 1. Chemical content of the travertine (GP-1 and GP-2) and the onyx (GP-3) in %

Element	GP-1	GP-2	GP-3
SiO_2	0.10	0,09	0,10
Al_2O_3	0.11	0,15	0,32
Fe_2O_3	0.17	0,50	0,11
MnO	0.096	0,064	0,33
MgO	1.64	2,05	2,70
CaO	51.10	51,50	49,83
Na_2O	0.04	0,037	0,04
K_2O	0.02	0,06	0,01
P_2O_5	0.062	0,051	0,071
Moisture (110^o)	0.035	0,038	0.033
Loss on ignition	45.89	45,02	45,05
Total	**99.283**	99,56	99,60

Note: The analyses GP-1 andGP-2 are travertine, while the analysis GP-3 is onyx.

PHYSICAL-MECHANICAL CHARACTERISTICS

An appropriate methodology of laboratory examination has been applied in the process of research in accordance with the existing standards of this type. The present state standards (MKS) are mostly used, but the recommendations of examination by the international society for mechanics of rocks (ISRM-**I**nternational Society for Rock Mechanics) were also considered.

Based on the performed evaluations, analyses and statistic elaboration the following description of the received values from the examined samples is presented:

MARBLE ONYX

- mean value for the strength to pressure in dry condition is σp=55,23 MPa
- mean value for the strength to pressure after 25 cycles of freezening and melting is σpm=48,66 MPa
- mean value of the index of strength parallel of the levelness of the onyx in dry condition Js (50) = 1,55 MPa
- quotient of proportionality K=σp/Js=55,23/1.55=35.63
- according to the value of absorption (U) the rock belongs to the class of rocks with low absorption of water (less than 0,5) (U=0.083%)
- mean value of weight capacity is γ=26,78 kN/m^3 (hard stone)
- quotient of resistance to ice is (Km=48,66/55,23=0,84)
- according to the strength to pressure it is considered medium strong rock (50-100 MPa)

TRAVERTINE

- mean value for the strength to pressure in dry condition is σp=69,60 MPa
- mean value for the strength to pressure after 25 cycles of freezening and melting is σpm=50,50 MPa
- mean value of the index of strength parallel of the levelness of the travertine in dry condition Js (50) = 3,97 MPa
- quotient of proportionality K=σp/Js=69,60/3,97=17,53
- according to the value of absorption (U) the rock belongs to the class of rocks with great absorption of water (2.5-5.0%) (U=3.06%)
- mean value of weight capacity e γ=23,77 kN/m^3 (medium hard stone)
- quotient of resistance to ice is (Km=50,50/69,60=0,72)
- according to the strength to pressure it is considered medium strong rock (50-100 MPa)

CONCLUSION

The travertine is compact and quite firm with not clearly distinguished striped texture, changing the not equal stripes of light brownish coloring and the thinner layers with lighter i.e. light greyish color. The color is light brownish – beige to lighter greyish glassy occasions which change irregularly. In separate parts of the travertine there are cracks filled with recrystallized calcite.

The marble onyx is characterized with large crystallized composition – structure and with compact, massive and slightly striped texture. The calcite crystals are thin, long and straw-like forms, crystallized diagonally on stratification. The onyx has light brownish and brown-yellowish color, with nuances of lighter and darker spots which gives the rock a better appearance.

Due to the petrographic-mineral character-istics, as well as the chemical content of the travertine and the onyx they can have great application. Primarily, the travertine can be used as architectural stone, i.e. for cutting tiles for surfaces. These are especially applicable for internal and external tiling on vertical surfaces. For the external surfaces the selection of the less cracked ones is a better choice. The remains of the cutting process may be used as macadam in concrete mixtures, as fillers for concrete pavement tiling, etc.

It was determined that the marble onyx is a relatively hard rock with low absorption of

water and with weight capacity which categorizes the rock in the group of hard decorative stones, with a quotient of resistance to ice within the normal limitation.
The travertine was determined to be a medium hard rock with high absorption values which categorizes the rock in the group of medium hard decorative stones, with a quotient of resistance to ice within the normal limitation.
According to the physical-mechanical characteristics it is considered a **high quality decorative stone** for internal and external decoration in the civil engineering.

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