

POSSIBILITIES FOR USING TRAVERTINE FROM THE NABIGORI DEPOSIT, VILLAGE OF VELMEJ (WESTERN MACEDONIA), AS ARCHITECTURAL STONE

Orce Spasovski, Daniel Spasovski

*Faculty of Natural and Technical Sciences, Institute of Geology, University "Goce Delčev" in Štip, Blvd. Goce Delčev, 89, Štip, Republic of Macedonia
orce.spasovski@ugd.edu.mk*

A b s t r a c t: The travertine from Nabigori, near the village of Velmej in western Macedonia, has been examined in order to determine the possibility to use it as architectural stone. The analyses and the laboratory examinations were performed on samples of travertine. The samples were taken from the surface parts. The results from their physical mechanical examinations showed that the rock mass itself satisfies the requirements to be used as an architectural stone, according the standards in Macedonia. The quality of the stone is higher in the deeper parts of the field where the external influences have very small effect. This stone has highly decorative features, and also it has fine grained structure which is a positive effect for the technical characteristics and processing.

Key words: travertine; Nabigori; architectural stone; mineralogic-petrographic composition; structural-textural characteristics; physical-mechanical characteristics

INTRODUCTION

The investigation area for travertine "Nabigori", village of Velmej is located in the western side of the Ilinska Bigla mountain. The location itself is on the west from the village of Velmej and around 32 km from the city of Ohrid (Fig. 1).



Fig. 1. Map of the R. Macedonia with location of the "Nabigori" deposit

The first relevant geological information is given by Cvijić (1906), based on the research done

in the beginning of the last century. During the period of the World War I, a few German geologists (Köber, 1952; Kossmat, 1924) worked in western Macedonia (Ilić, 1940) for the area Resen–Kruševo draw a geological map 1:100 000 and he was the first that shown that the granits are formed later than the schists (Jardanov, 1947, 1951) performed geological investigation on the area Debar–Ohrid. (Mihajlović, 1951) shown that the region of the Lake Ohrid is one of the most active seismic regions in Macedonia (Izmajlov, 1956) during the researches for iron ore in western Macedonia also explored the Galičica-Petrina region (Ivanovski, 1957) conducted geological mapping of the southwestern parts of the mountain Galičica 1:25 000. (Ivanovski and Nestorovski, 1968) considered that western Macedonia, as tectonic unit, belongs to the inner Dinaride belt and it is characterized with linear foldings, over thrusts and imbricated structure. Creation of the basic geological map on the SFRY, authors of the sheets Ohrid and Pogradec in ratio 1:100 000 Dumurdžanov and Ivanovski, 1972, in the Interpreter, they processed the lithological composition of the rocks in the sheets Ohrid and Pogradec in details, and described the rocks that covered the appearance of travertine in the region of Nabigori. Bundeovski, 1974 prepared the

first elaborate for the results from the geological investigations for travertine in Nabigori, Bučište

(Paskalev et al., 1997) prepared the elaborate for ore deposits reserves in the site Nabigori.

GEOLOGICAL CHARACTERISTICS

In the geological constitution of the site Nabigori the following types of rocks are present: metasand stones, marbleized limestone, travertine and proluvial deposits (Fig. 2).

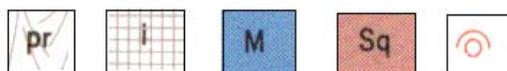
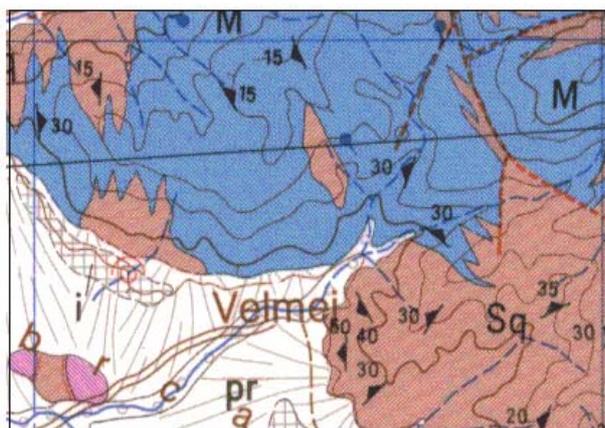


Fig. 2. Geological map of the deposit Nabigori
pr – Proluvium, i – Travertine, M – Marbleized limestone,
Sq – Metasandstones, @ – Occurrences of decorative stone

Metasandstones (Sq)

Metasandstones are represented as bigger mass on the south-east parts of the site and they are the most common lithological members. They are not connected to a certain level, but occurs in different horizons of the stratigraphic column, where they change laterally and vertically with a phyllitic shales, as thin seam or large masses. These rocks are fine and coarse granular, dark to light grey, composed mainly by quartz, and less with sericite and pieces of metaquartzite. Secondly, they contain feldspar, calcite, titanite, zircon, granate and tourmaline. Locally, in quite great amount, is found graphite-bituminous matter, from which origins the dark color of the rocks. Inside the metasandstones are developed thin seams of metaquartzites, from light grey to dark grey color.

Marbleized limestone (M)

They can be found in the most upper parts of Devonian. In the past they were widely spread, but today they are found mostly in small erosive rocks, and in larger masses are preserved north and north-east of the village of Velmej. Thin seams and small

lenses are noted in the upper horizons of the phyllitic shales. The limestones are pink, grey or black-grey, in the lower parts are plate shaped, and in the upper parts are massive. The intensity of marbleization decreases towards the higher horizons. They are fine granular to massive, composed partly of precrystallized calcite matter. Black-gray varieties contain graphite-bituminous matter.

Travertine (i)

Travertine is found in the edge parts of the Pliocene basin near to the limestone. They are noted in five localities with different size. From economical aspect, the most interesting are occurrences in Nabigori. The travertine is found with dimensions from 500×200 m to 100×20 m.



Fig. 3. Manifestation of layers of travertine on the surface of the terrain



Fig. 4. Stripped travertine from the Nabigori deposit

With the researches is found that the thickness is very variable and varies from 5 to 25 meters (Fig. 3). Also, they are different in color and the mechanical strength. In the site of Nabigori, travertine is cream to pink color and with strength within the range of travertine in Macedonia (Fig.4). With investigations in this site are found arties of travertine with weak diagenesis, and some where are represented as travertine sands.

APPLIED RESEARCH METHODS

Mineralogic-petrographic examinations were performed at the Faculty of Natural and Technical Sciences, Institute for Geology, by the authors of the paper, while the chemical composition of the travertine was analyzed at the chemical laboratory of Železarnica Skopje.

Examination of the physical-chemical characteristics was done at the laboratory of the Faculty of Civil Engineering in Skopje. The researches

Proluvium (pr)

Proluvial sediments are found very of ten and they are represented with coarse clastic unsorted, partially processed or unprocessed material composed of the rocks that build the surrounding terrains.

were performed in 2010. Because the rocky masses are not well uncovered, the samples were taken from the surface of the terrain. As a consequence, in the samples are found cracks as a result of the increased atmospheric influence. However, the samples have shown credible values of physical-mechanical characteristics. Undoubtedly, the samples taken from the deeper layers would show better results.

PETROGRAPHIC–MINERALLOGIC CHARACTERISTICS

Represented samples from Nabigori have been selected for the petrographic-mineralogic examinations. The petrographic preparations were made, reviewed microscopically with a polarized microscope with transmitting light brand Leitz, Wetzlar Germany. The petrographic-mineralogic examinations were done at the Faculty of Natural and Technical Sciences at the Institute for Geology by the authors of the paper.

The travertine has red-brown colour with rare irregular forms that are light coloured. They are characterized with fine grained composition, compact, massive and fairly hollow texture. Cracks are rarely found, small with length of 2 mm.

Under microscope, the rock is fine grained and composed of small calcite grains woven with

clay and limonite matter. On some places were seen small cavities filled with additional calcite, which is large crystal, clear and pure.

The rock is made of calcite, which basically is with crypto-crystal form and structure. The calcite structure often makes irregular oolitic shapes, round and oval with zonal structure of the calcite mass (Figs 5a, 5b). The rock is filled with recrystallized calcite – microcrystal and pure. The granulation of the calcite in these forms is around 50 μ . The irregular forms are rarely found, gloomy brownish i.e. strongly coloured with limonitized oxide. As secondary minerals appear quartz grains and rarely lamina of mica, and it can also be said that there are only residues.



Fig. 5a. Microphotography of sample H⁻¹ 10×(N⁻)

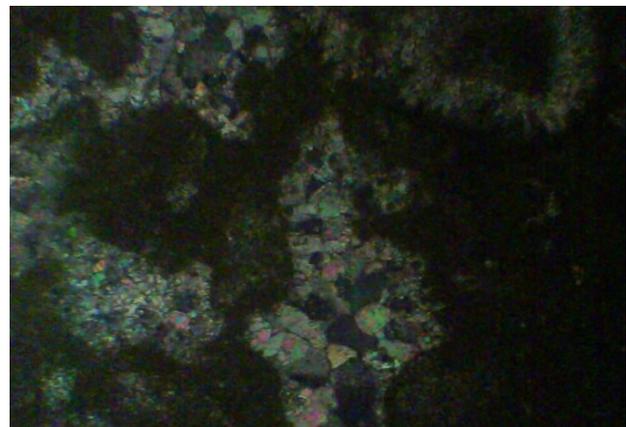


Fig. 5b. Microphotography of sample H⁻² 10×(N⁺)

CHEMICAL EXAMINATIONS

The chemical characteristics of travertine from the locality of Nabigori, 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 colour and the manner of their appearing, these rocks are clearly different from the surrounding ones.

The samples H⁻¹ and H⁻² are travertine, with quite pure calcite composition. According the chemical analysis of the samples, the participation of MgO is between 0.80 of 1.10 % (Table 1).

With the performed chemical and petrographic examinations researches is confirmed that it is carbonate mass, actually travertine with all its specificities. Performed are physical-mechanical

investigations. The values are within the range of travertine in Macedonia.

Table 1

<i>Chemical composition of travertine</i>		
Component	H ⁻¹	H ⁻²
SiO ₂	0.23	0.21
Fe ₂ O ₃	0.17	0.17
Al ₂ O ₃	0.07	0.06
CaO	54.45	54.26
MgO	0.80	1.10
Na ₂ O	0.60	0.70
K ₂ O	0.02	0.02
P ₂ O ₅	0.04	0.05
Wet (110°)	0.02	0.02
Heat losses	43.60	43.41
Total	100.00	100.00

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. Mostly used are existing state standards (MKS), but the recommendations of examination by the international society for mechanics of rocks (ISRM – International Society for Rock Mechanics) were also considered.

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

- mean value of the strength to pressure in dry condition is $\sigma_p = 75.80$ MPa;
- mean value of the strength to pressure after 25 cycles of freezing and melting is $\sigma_{pm} = 75.80$ MPa;
- according to the value of absorption (U) the rock belongs to the class of rocks with great absorption of water (1.67%);
- toughness, according to the method of Treton – the loss of weight is 7.5%–
- wearing, according to Bohme – the quotient is $K_a = 3.14 \text{ cm}^3/50 \text{ cm}^2$
- strength of the edge to pressure – the loss of weight is 32.3%.

Quality and technological characteristics

The excavated blocks from each layer are taken to the factory for processing in Cer. The cutting of the blocks is with diamond saw with a diameter of 2.000 m and with gang-saw.

Cutted are plates of 2 cm and is got utilization of 16 m²/m³ pro-block. It is found that the travertine can be nicely cutted, can be polished and takes a great shine. The plates are very hard and look very decorative (Fig. 6).



Fig. 6. Commercial plates of travertine ready for market

From the travertine are made blocks for rehabilitation of the Stone Bridge in Skopje. Processing had shown that it can be processed in all the forms that were present on the bridge before.

Beside the massive and compact travertine, there are decomposed dusty, which can be applied successful in the civil engineering as fillers.

CONCLUSION

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

It is found that the travertine can be cut well, can be polished and takes a great shine. The plates are very hard and look very decorative.

According the petrographic-mineralogic characteristics, as well as the chemical content, travertine can have wide application. Primarily, the travertine is especially applicable for internal and external tiling on horizontal and vertical surfaces. Mainly, it is used for external tiling and protection

of the walls from the destructive atmospheric influence, especially moisturising and freezing. Travertine in form of thin smooth plates can be used for the interior design for tiling of the inner walls of the rooms where there is great frequency of people, as well as the walls of the bathroom and toilets. Very often, the decorativity of the travertine allows using and manufacture of the floors on the wide common rooms, on stairs, which gives better aesthetic appearance of the space an easy maintenance and long-life compared with the surfaces made of concrete, wood, tire or other synthetic-plastic masses. This dues to the fact that travertine used for this purpose has great resistance of wearing. Travertine is used for manufacture of the accessory in the toilets and the public objects, luxury hotels, schools, hospitals and other objects.

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Резиме

МОЖНОСТИ ЗА КОРИСТЕЊЕ НА ТРАВЕРТИНОТ ОД НАОЃАЛИШТЕТО НАБИГОРИ, С. ВЕЛМЕЈ (ЗАПАДНА МАКЕДОНИЈА), КАКО АРХИТЕКТОНСКИ КАМЕН**Орце Спасовски, Даниел Спасовски**

*Факултет за природни и технички науки, Институт за геологија, Универзитет „Гоце Делчев“,
бул. Гоце Делчев, 89, 2000 ШТИП, Република Македонија
orce.spasovski@ugd.edu.mk*

Клучни зборови: травертин; Набигори; архитектонски камен; минералешко-петрографски состав; структурно-текстурни карактеристики; физичко-механички карактеристики.

Травертинот од Набигори (с. Велмеј, западна Македонија) е испитуван со цел да се утврди можноста за користење како архитектонски камен. Анализирте и лабораториските испитувања беа извршени на примероци од травертин. Примероците се земени од површинските делови. Резултатите од нивните физичко-механички испитувања покажаа дека карпестата маса ги исполнува сите бара-

ња за употреба како архитектонски камен според државните стандарди на Р. Македонија. Исто така, квалитетот на каменот е повисок во подлабоките делови на теренот, каде што надворешните влијанија имаат многу мал ефект. Овој камен има високи декоративни својства, а ситнозрестата структура претставува позитивен ефект за техничките карактеристики и подложност на обработка.