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POTENTIALITY OF RADOVAC GRANITE (SERBIA) FROM THE ASPECT OF THE ARCHITECTURAL STONE

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A b s t r a c t: Radovac granite outcrops are situated in the area of Kosmaj Mountain in central Serbia. Many authors have engaged in petrologic examinations of this granite, but the detailed examinations of its physico-mechanical properties from the aspect of use as an architectural stone have never been conducted before. We have conducted field observations with collecting testing specimens, laboratory examinations of these specimens, potentiality evaluation from the aspect of the architectural stone, and presented the data herein. The results of thorough examinations have shown that this rock can be used as an architectural stone with excellent quality of rock mass and aesthetic properties. However, due to scarce outcroppings, these results have limited use since vast volume of rock-mass of the batholith remains covered and unexamined.

Key words: granite; Kosmaj; Serbia; architectural stone

INTRODUCTION

The granite mass of Radovac is outcropping in the SW foothill of the Kosmaj Mt. in central Serbia, about 40 km south from the Serbia's capital, Belgrade. According to geomagnetic surveys [1], this batholith extends beneath the whole area between Kosmaj Mt. and Barajevo city, some 18 km to the NW, but is manifested on the surface with only small outcroppings opened by Radovac stream flowing over it and also by extensive contact metamorphism products and hydrothermal Pb-Zn deposits in the area Kosmaj-Babe. Outcrops are presented in the Basic geologic map of Yugoslavia, sheet Smederevo [2] as four small, relatively isometric masses, but their real appearance in the field is much more complicated, depending on the flow of Radovac stream.

GEOLOGICAL SETTING

The granitic mass of Oligocene age (30-29 Ma, [3]) has intruded the Late Cretaceous (Turonian-Maastrichtian) flysch and turned it into hornfels. Volcanic rocks (quartzlatite and volcaniclastic formations) are present further North (Babe area). All these formations are partially covered by Miocene and Pliocene sediments (Fig. 1).

The position and tectonical setting of the batholith was structurally controlled by the extent of the Central deep fracture of the Vardar zone [1], and its intersections with transverse faults which caused the formation of the Neogene sedimentary basin.

Within the classification of the Tertiary igneous formations of Serbia [4], Radovac granite falls into the Late Paleogene/Early Neogene granitoid suit of Dinarides. Mineral and chemical composition of granite shows it is calc-alkaline in character, belonging to the group of I-type granitoids [3]. Table 1 shows the chemical composition of this granite.

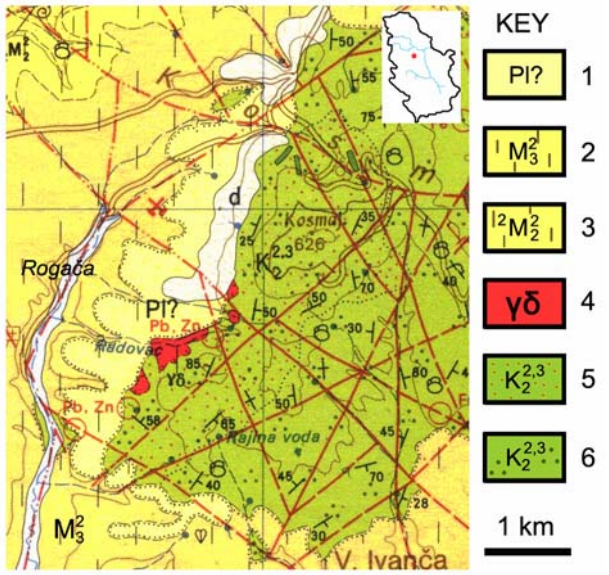


Fig. 1: Geology of Kosmaj Mt. [2]
Key: 1. conglomerate of Pliocene age; 2. sand, sandy clay and sandstone of Miocene age (Messinian); 3. clay, sand, sandstone and gravel of Miocene age (Tortonian); 4. Radovac granite; 5. hornfels; 6. flysch: sandy marlstone, sandstone and limestone of Late Cretaceous age (Turonian-Maastrichtian).

Table 1

Chemical analysis results [5].

Component	Content (%)
SiO_2	63.77
TiO_2	0.63
Al_2O_3	15.38
Fe_2O_3	2.07
FeO	2.56
MnO	0.05
MgO	1.98
CaO	4.46
Na_2O	3.28
K_2O	4.18
P_2O_5	0.24
H_2O^{+110}	0.57
H_2O^{-110}	0.84
Σ	99.93

EXPERIMENTAL SECTION

During our study, we have used A. field study observations and B. laboratory examinations – a) microscopic examination in transmitted light (photomicrograph capturing was performed on Petrology department of the Faculty of Mining and Geology – Belgrade University, Serbia, on polarizing microscope for transmitted light type Leica DMLSP with digital camera), and b) testing of physico-mechanical properties of the rock-mass statutory by the Serbian standard SRPS B.B3.200 for the architectural stone, performed in the Stone and Aggregate Laboratory of the Materials Testing Institute in Belgrade.

RESULTS AND DISCUSSION

Field study

Road network in this area is well developed, but there is no road leading to the very outcrop area in Radovac stream. Outcrops are surrounded by thick forest. Hornfels are above water-table level and granite is underneath it. Due to inaccessibility of outcrops and their position mostly under the level of water-table, this granite has never been quarried or used as a building stone.

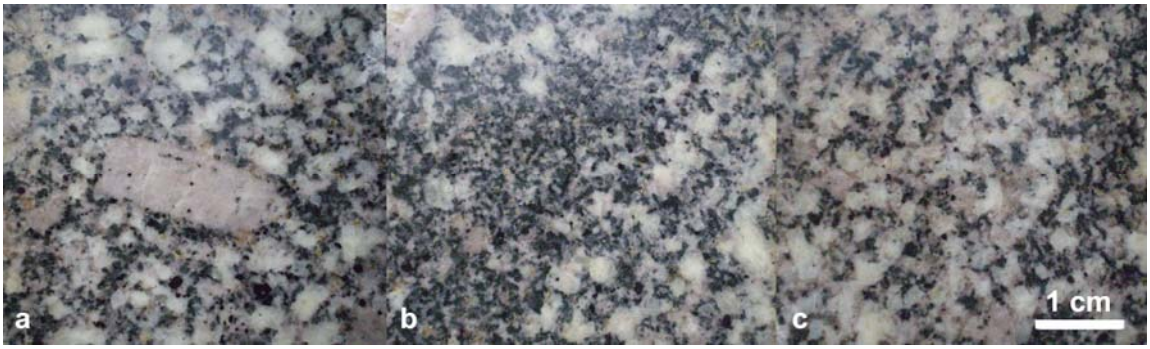
Granite is coarse-grained, grey in colour, with porphyritic grains of alkali-feldspar, lilac in colour and up to 6×3 cm, but most often around 2 cm in size (Fig. 2). Granite contains numerous xenoliths – mostly hornfels originating from flysch sediments, dark grey in colour, from 5 mm to around 10 cm in diameter, of isometric to irregular shape (Fig. 3).

Fig. 2: Porphyritic grains of feldspar ("F").

Fig. 3: Irregular-shaped xenolith ("X").

Xenoliths are on mutual distance of around few decimetres. Jointing is mostly massive, while bordering zones of the magmatic body show tabular, platy blocks with plate thickness of around 10 cm. The rock-mass shows slight variations in appearance (Figs. 4a, b, c). The aesthetic properties of this rock are ranked as the highest among all magmatic rocks of Tertiary age in the Vardar zone of Serbia.

Outcrop parts accessible for examination show no visible hydrothermal alterations. Parts exposed to the impact of Radovac stream are intensively weathered and decomposed, while parts out of the stream reach are so hard it is impossible to break off specimens for testing (due to this fact, we were forced to take the specimens for testing from the stream, which were partially altered).



Figs. 4: Variations in appearance visible on plane-cut stone surfaces.

Microscopic Examination

The rock has a hipidiomorphic grainy texture, homogenic structure and is composed of feldspars (orthoclase and plagioclase) and quartz as main components, with hornblende and biotite as subordinate components, and apatite, sphene and metallic minerals as accessory (Figs. 5a, b). Plagioclase grains are idiomorphic to hipidiomorphic, polysynthetically twinned, and 0.4×0.2 to 10×5 mm in size, often altered to sericite in a varying degree. Orthoclase grains are idiomorphic to alotriomorphic, 0.4×0.2 to 5×4 mm in size, mostly fresh. Twin forms are rare. Quartz grains are hipidiomorphic to xenomorphic, sometimes slightly fractured, mostly interstitial. Hornblende grains are hipidiomorphic to xenomorphic, elongated forms, up to 5×3 mm in size. Along the grain boundaries, hornblende is altered into chlorite, calcite, sphene, magnetite and epidote. Biotite grains are platy to irregular, with numerous apatite inclusions. Two types of biotite are present – one formed in magmatic phase and the second formed by alteration of hornblende.

Testing of physico-mechanical properties

The results of the testing, presented in Table 2, have shown that the stone is heavy according to its bulk and particle density; slightly porous; water absorption is small; compressive strength is medium-high; according to abrasion resistance, the stone is hard (the evaluation according to [6]). As mentioned, the specimen was already partially altered, so these results do not show the completely realistic picture of the Radovac granite quality. Nevertheless, according to the technical specifications of the Standard B.B3.200 and the obtained testing results, Radovac granite can be used as an architectural stone for interior paving and cladding with no limitations; for the exterior cladding limited up to 30 m in height; and for exterior paving limited to the intensive and moderate pedestrian traffic.

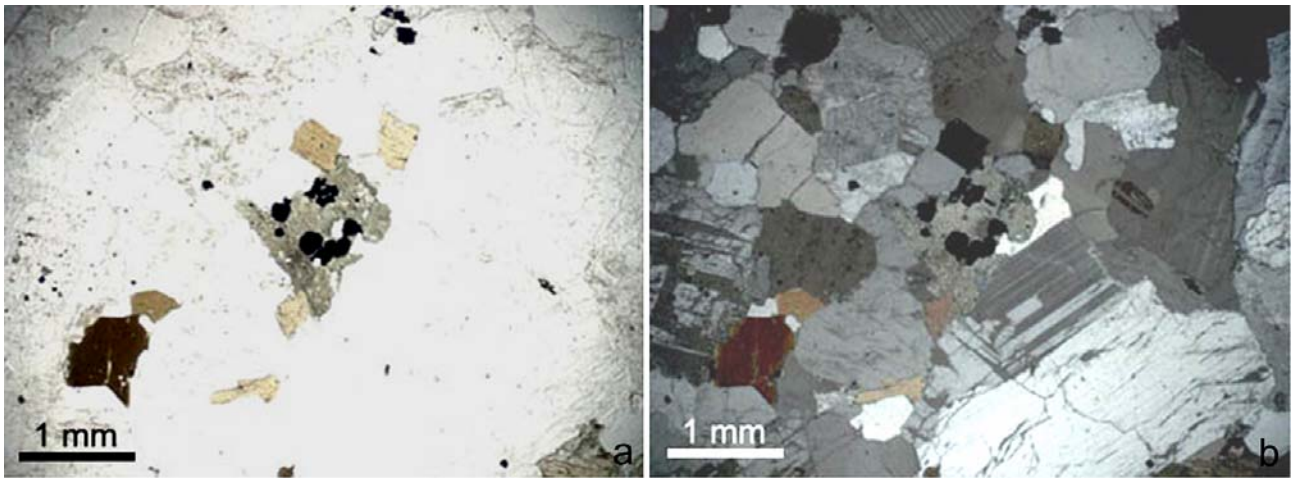


Fig. 5: Photomicrographs of granite (a – under parallel Nicol prisms, b – under cross-polarized light).

Table 2

The results of lab testing of physico-mechanical properties.

Property	Serbian standard	Measuring units	Testing results – data ranges and average values
Frost resistance	B.B8.001	–	good
Resistance to crystallization of Na_2SO_4	B.B8.002	–	good
Water absorption	B.B8.010	%	0.40–0.50 0.46
Compressive strength	B.B8.012	MPa	–
dry			110–182 147
water-saturated			96–151 121
after 25 freeze-thaw cycles			96–135 119
Abrasion resistance	B.B8.015	$cm^3/50\ cm^2$	9.49–11.04 10.15
Flexural strength	B.B8.017	MPa	14.12–16.35 15.05
Bulk density	B.B8.032	g/cm^3	2.648–2.700 2.670
Particle density		g/cm^3	2.703–2.727 2.719
Porosity		%	1.8
Thermal expansion	ISO 10545-8	mm/m	0.505–0.543 0.525
Linear thermal expansion coefficient		$\cdot 10^6$ 1/ºC	6.560–7.270 6.940

CONCLUSION

Radovac granite is opened through small outcrops situated in the SW foothill of the Kosmaj Mountain in central Serbia, about 40 km south from Belgrade. The rest of at least 18 km in length batholith is still covered and manifested at the surface through extensive metamorphism of Cretaceous flysch sediments and hydrothermal Pb-Zn deposits. From the aspect of the architectural stone, Radovac granite, i.e. its unweathered parts have the following favourable properties: tenacity, freshness, homogeneity, good aesthetic properties, massive jointing. Unfavourable property is the presence of xenoliths. Laboratory examinations of Radovac granite have shown that its physico-mechanical properties satisfy the requirements of the Standard B.B3.200 and it can be used as an architectural stone for interior paving and cladding with no limitations; for the exterior cladding limited up to 30 m in height; and for exterior paving limited to the intensive and moderate pedestrian traffic. On the general, the batholith is only opened through small outcrop area which is not enough for a reliable potentiality evaluation.

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Р е з и м е

МОЖНОСТИ НА ГРАНИТ ОД РАДОВАЦ (СРБИЈА) ЗА КОРИСТЕЊЕ КАКО АРХИТЕКТОНСКИ КАМЕН

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Клучни зборови: гранит; Космај; Србија; архитектонски камен

Во областа на планината Космај во Централна Србија има жили на гранитот од Радовац. Многумина автори вршеле петролошки испитувања на овој гранит, но никогаш досега не се спроведени детални испитувања на неговите физичко-механички својства од аспект на негово користење како архитектонски материјал. Ние извршивме теренско собирање на примероци нивно лабораториско испитување и оцена на можноста овој гранит да се употребува како архитектонски камен. Резултатите покажаа дека тој има одличен квалитет на камената маса и естретски својства. Сепак, поради реткоста на жилите, бидејќи најголем волумен на камената масата останува неоткриен и неиспитан.