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Original scientific paper

THE POSSIBILITY OF USE OF KREMIĆ GRANITOID (SERBIA) AS AN ARCHITECTURAL STONE

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A b s t r a c t: The stone from the granitoid pluton of Kremić in southern Serbia has been examined in order to evaluate the possibility of its use as an architectural stone. Both field observations and laboratory testing of specimens have been performed. Although the specimens were collected from the field surface level, their physico-mechanical lab test results have shown that the rock mass itself fulfils all the requirements for use as an architectural stone set by the State through Serbian standards. Also, the stone quality is higher in deeper ground levels, where the weathering agents have less intense effects. This stone does not have high ornamental properties, but it has a fine-grained texture and low mica content which has a positive effect on its technical characteristics and susceptibility to processing.

Key words: granitoid; pluton; southern Serbia; architectural stone

INTRODUCTION

Kremić pluton is one of the many investigated under the author's dissertation whose theme is the potentiality of Vardar zone magmatic masses for use as an architectural stone. This plutonite is particularly interesting because it hasn't been investigated from this aspect before and the rock mass fulfills all the requirements for architectural purposes and, unlike other plutons in the Vardar zone, this rock does not contain excessive pyrite.

The Kremić granitoid pluton is situated in southern Serbia, NE from the city Raška. The majority of authors consider it the part of Kopaonik pluton (Urošević et al. 1973; Janković, 1990; Karamata et al. 1992), situated 2 km to the east, on the very border with Kosovo. A belt of schists and serpentinites separates these two plutons at the surface. The present level of erosion yields a Kremić granitoid plutonite surface of about 7 km^2. Due to poor accessibility and scarce outcroppings, Kremić granitoid is by far less examined compared to the near-by Kopaonik pluton. Also, the architectural stone has never been extracted in it, nor has its potentiality for this purpose been evaluated.

GEOLOGICAL SETTING

The oldest uncovered rocks belong to the upper Paleozoic low-metamorphic series of schists, metabasites, marble etc., known as Veleš series (Wilson, 1933). Magma that gave Kremić granitoid pluton intruded the Veleš series schists, serpentinites and volcanic complex, and metamorphosed them (Mićić, 1966, 1980). Serpentinized periodtites, mostly hartzburgites, represent a part of the "Ibar ultramafic complex". The proximity of the three main fault zones of the Vardar zone in Kopaonik area (Vukašinović, 2005) caused the intense magmatic activity. Volcanic rocks – dacito-andesites, lamproandesites, pyroxene-amphibole andesites, volcanic breccias etc., mostly hydrothermally altered, were formed in Oligocene-Miocene (Urošević et al. 1973). The geological setting is shown in Figure 1.

In geotectonic sense, all the plutonic masses of Kopaonik area (Kremić, Željin, Drenje, Crvanj etc.) belong to the Vardar zone, i.e. its sub-unit – Kopaonik unit or block-ridge terrane (Dimitrijević, 1995; Karamata, 1995, 2006; Robertson et al. 2009). This sub-unit spreads to north towards Belgrade and to the south continues into Paikon unit in Greece (Karamata, 2006; Robertson et al. 2009). Magma is intruded into so-called Kopaonik anticline which is disrupted by the east-west trending faults. This fault system was the main magma conduit (Karamata et al. 1992).

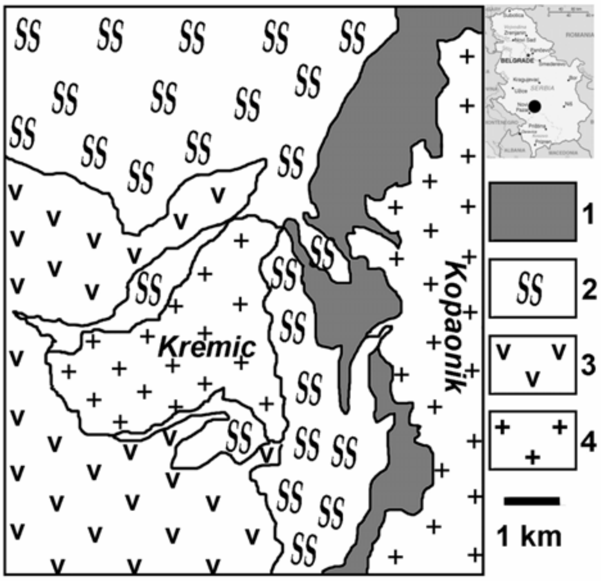

Fig. 1. Location of Kremić granitoid in Serbia (up, right). Simplified geologic map (left) of Kopaonik-Kremić area. Key: 1 – Veleš metamorphic series, 2 – serpentinized peridotites, 3 – volcanic rocks, 4 – plutonic rocks.

Petrologic and mineral composition and age

Many authors consider Kremić pluton to be a marginal facies of Kopaonik pluton, based on identical chemical (Table 1) and mineral compositions. Granodiorite, amphibole-biotite quartz-diorite and biotite quartz-monzonite with K-feldspar porphyroblasts show mutual transitional boundaries (Urošević et al. 1973; Janković, 1990; Karamata et al. 1992). Subvolcanic rocks (microgranodiorite, microquartzdiorite, aplite, pegmatite, lamprophyre) are also present (Mićić, 1966).

The rock texture is hypidiomorphic granular, in places grading into inhomogeneous granular close to porphyritic. General mineral composition: andesine (zonal, average An38.5 %), orthoclase (cryptopertite, sometimes partly transformed into microcline), quartz (undulate), biotite (more or less transformed into hornblende), hornblende, accessories (magnetite, apatite, zircon, ortite, sphene) (Karamata, 1957).

Table 1

Chemical composition of Kremić granodiorite (Mićić, 1980)

Component	Content (%)
SiO_2	60.56
TiO_2	0.70
Al_2O_3	17.69
Fe_2O_3	2.85
FeO	3.05
MnO	0.06
MgO	3.17
CaO	5.75
Na_2O	1.94
K_2O	2.96
P_2O_5	0.30
$H_2O^{+110°}$	1.22
$H_2O^{-110°}$	0.09

Tertiary granitoid rocks of Kopaonik area belong to the Dinaric suite of calc-alkaline magmatic formation of Serbian part of the Balkan peninsula, of late Paleogene-early Neogene age (Cvetković et al. 2002). According to Urošević et al. (1973), all the small plutonic masses in the area were formed in the same cycle of magmatic activity and are supposed to represent the parts of a larger, still covered pluton. All these granitoids are I-type, with identical trend from quartz-diorite to granodiorite and quartz-monconite, locally granite (Karamata et al. 1992).

Isotopic age analyses (Karamata et al. 1992) have shown that all the plutons in Kopaonik area were formed penecontemporaneously, in Oligocene (K/Ar age 29-35 Ma). K/Ar analysis for Kremić granitoid yielded the age of 32 Ma (on biotite).

TESTING METHODS

As a part of the PhD dissertation, and in accordance with regulatory provisions valid in the Republic of Serbia, the stone from Kremić granitoid pluton has been examined according to Serbian standards – SRPS.B.B3.200:1994 as the basic one and the standards cited therein. The testing is performed in The Stone and aggregate Laboratory of the Materials testing institute in Belgrade. Field examinations were performed during 2009, on available outcrops, on the regional prospecting works level (Vakanjac, 1976). Since the rock mass is not well uncovered, the specimens taken originate from the field surface. As a consequence, there were some hidden fractures in lab samples due to increased weathering level. However, the testing samples have shown plausible values of physico-mechanical characteristics. Undoubtedly the specimens from greater depth will show even better results.

Testing results

Field works. The available crop is situated near the granitoid-serpentinite contact. Granitoid rock has a grey colour, varying from darker to lighter shades. The heterogeneous look is due to more or less dense disposition of mafic minerals. The general look of this rock is very similar to marginal facies of Kopaonik pluton.

The rock has irregular and platy jointing. The plates are about 40 cm thick, cracked into smaller fragments of the longest axis up to 50 cm (Figure 2). Along some plate boundaries the weathering disintegration occurs. The deeper rock parts have blocky setting. Fracture systems have dip direction and dip angle: 127/56 (dividing the rock into plates); 198/50; 30/53 and 147/84 (dividing the plates into smaller pieces).

Topsoil is around 20 cm thick. In more weathered parts the feldspars become lustreless and stained with limonitic colouring and mafic minerals oxidized. On the granitoid-serpentinite contact, both rocks are intensely altered and powdery.

In spite the fact that the rock is exposed to weathering, it is compact and breaks hardly. Deeper parts are increasingly more fresh and compact.

Aplitic-pegmatitic veins are present, but far less than in adjacent plutons (Drenje, Željin).

Fig. 2. Platy jointing of Kremić granitoid rock.

Xenoliths of various shapes and sizes are present (Figure 3). Some look like the host rock, some are more mafic, others resemble schists. The most is up to 5 cm and isometric in shape.

The texture of the rock is fine-grained, the structure is homogenous. The hornblende grains show lineation only in the border zones.

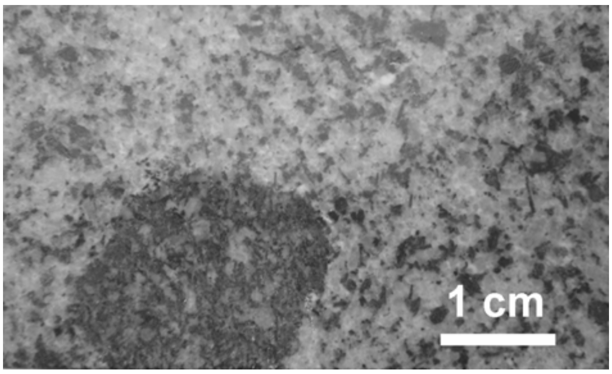

Fig. 3. Xenolite in Kremić granitoid rock.

Lab testing

Physico-mechanical properties testing and microscopic study. Some testing prisms when cut show cracks and fissures. They break mostly along these cracks during testing. Possibly also the presence of large grains predisposes the surface of break. Flexural strength prisms with no cracks have shown very high values, and those with cracks broke immediately and have therefore not been taken into account. The breaking surface is irregular and rough.

Table 2

Lab testing results of physico-mechanical properties for Kremić stone.

Property	Standard SRPS	Units	Testing results	
			variation range	average value
Frost resistance	B.B8.001	–	no visible changes	durable
Resistance to Na_2SO_4	B.B8.002	–	no visible changes mass loss 0.01–0.03%	durable 0.02% mass loss
Water absorption	B.B8.010	%	0.23–0.68	0.40
Compressive strength				
– dry	B.B8.012	MPa	153–189	169
– water saturated			100–164	136
– after 25 freeze-thaw cycles			95–154	134
Abrasion resistance	B.B8.015	$cm^3/50\ cm^2$	9.71–10.59	10.01
Flexural strength	B.B8.017	MPa	31.06–32.51	31.97
Apparent density		g/cm^3	2.660–2.698	2.678
Real density	B.B8.032	g/cm^3	2.703	2.703
Density coefficient		–	0.991	0.991
Porosity		%	0.9	0.9

MINERAL AND COMPOSITION

Macroscopic petrographic examination

Both felsic and mafic minerals can be observed. Felsic are feldspars and quartz, mafic comprise hornblende and biotite. Most grains are up to few millimetres. Only the largest K-feldspar porphyroblasts reach over 1 cm.

Feldspars are whitish-grey, translucent to opaque, sub- to anhedral. The samples from the greater depth contain more fresh and translucent feldspars. The largest porphyroblasts have pale purple colour. K-feldspar porphyroblasts occurrence is not rare in Vardar zone granitoid plutons; Divljan and Cvetić (1991) explain its origin by postgenetic K-metasomatosis on a regional scale.

Quartz is rare, probably due to increased basicity of these marginal parts of the intrusion. The grains are mostly isometric in shape, colourless, transparent and cracked.

Mafic minerals grains are mostly up to 1-2 mm in size. Hornblende grains are subhedral, sometimes up to (9x4) mm in size. Euhedral hornblende grains are more rare and up to (8x5) mm in size. In the samples taken from the surficial level, it shows oxidation signs but deeper in the rock mass it is more fresh.

Biotite content is smaller than hornblende; flakes are subhedral, fresh, black in colour, most often up to 2 mm, rarely up to 4 mm in length. Flake aggregates are up to 5-6 mm thick.

Microscopic study

The rock contains plagioclase, quartz, orthoclase, biotite, amphibole and pyroxene.

Plagioclase makes up around 50% of the rock. The grains are most often prismatic, rhombic and xenomorphic. Grains show minor alteration. Larger grains are poikilitic, containing metallic minerals, biotite and apatite. Synthetic and lamellar twins are present.

Quartz is intergranular, xenomorphic, rarely with cataclastic parts. Makes up about 20 % of the rock.

Orthoclase is present as large, xenomorphic to ellipsoidal grains, mostly up to (3x3) mm, with minor sericitization; poikilitic, containing plagioclase and mafic minerals.

Biotite is mostly fresh, tabular, with etched margins, rarely chloritized. Often spatially connected with hornblende into small aggregates of mafic minerals.

Amphibole is represented with hornblende of variable chemistry, reflected through colour changes from green to brown. Grains are xenomorphic to hypidiomorphic, altered in a variable degree.

Clinopyroxene has oval grains up to (0.3×0.2) mm, mostly altered.

Metallic minerals occur as grains under 0.1 mm, round or angular, sometimes making up the small piles. Apatite is most often poikilitically caught up in larger grains of other minerals.

Texture: hypidiomorphic granular.

Structure: homogenous

Rock type:

– according to mineral composition: granodiorite

– according to chemical composition: transition from granodiorite to quartz monzodiorite

Crystallization order: biotite, hornblende, clinopyroxene, plagioclase, orthoclase, quartz.

DISCUSSION – EVALUATION OF THE TESTING RESULTS

According to Bilbija (1984) criteria, physico-mechanical properties of the stone are characterizing the tested stone in the fallowing way:

– Density value characterizes it as a heavy stone.

– Porosity characterizes it as being compact.

– Water absorption is very low.

– Resistant to freeze and salt crystallization actions.

– Compressive strength is high.

– Abrasion resistance characterizes it as being on the boundary between hard and very hard.

According to the requirements prescribed in the standard SRPS B.B3.200, and the results of the physico-mechanical properties testing, this stone can be used for paving and cladding both in exteriors and interiors, for all load categories.

CONCLUSION ON USAGE AS AN ARCHITECTURAL STONE POTENTIALITY

The specimens for testing were taken from the surface where weathering was most intense, yet, lab testing results have shown that this stone is in full accord with the requirements of the Serbian standards. In the deeper ground levels, the rock mass passes from platy to blocky and is less affected by weathering, and will have even better results. Based on the results of all the examinations, it is concluded that the stone from Kremić granitoid pluton can be used as an architectural stone.

This rock is fine to medium-grained and has low mica content, which gives it a great potential to have plausible physico-mechanical properties and susceptibility to processing (cutting, polishing etc.). Absence of pyrite gives it a time perseverance for external applications. The flaws of this stone are the following: average ornamental value, heterogeneity of the appearance; xenoliths. However, this rock mass is barely opened by the erosion and there is a great possibility that is becomes more ornamental in its deeper parts, alike the nearby Kopaonik pluton that many authors consider Kremić pluton to be a part of. Kopaonik pluton is now included into the territory of a National park with no mining allowed; heterogeneity of the appearance becomes imperceptible after the stone is polished and also when the slabs are riven (Figure 4). It should be noted that in Serbia today, almost all the architectural stone comes from the import under the excuse that Serbia has no good quality stone deposits.

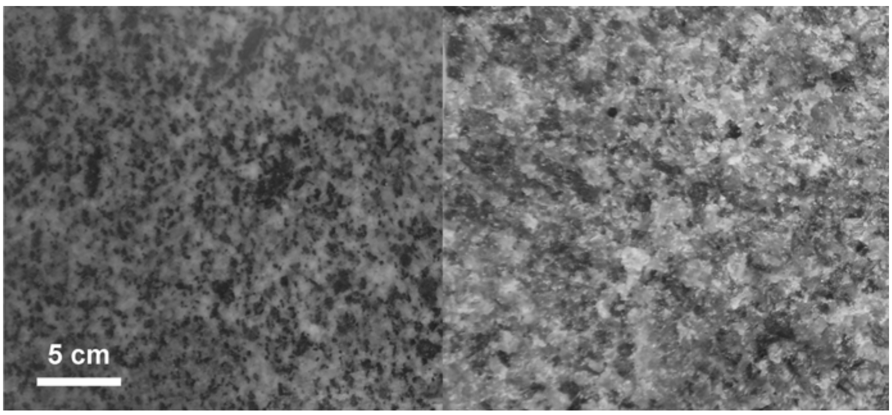

Fig. 4. The look of the polished (left) and riven (right) surface.

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Р е з и м е

МОЖНОСТ ЗА УПОТРЕБА НА ГРАНИТОИДОТ КРЕМИЌ КАКО АРХИТЕКТОНСКИ КАМЕН

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Клучни зборови: гранитоид; плутон; јужна Србија: архитектонско-градежен камен

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(Makreski et al., 2004): Makreski Petre, Jovanovski Gligor, Stafilov Trajče, Boev Blažo, 2004: Minerals from Macedonia, XII. The dependence of quartz and opal color on trace element composition – AAS, FT IR and micro-Raman spectrocsopy study. *Bull. Chem. Technol. Macedonia,* **23,** 2, 65–212.

Scientific meetings:

(Stojanov, 1990): Stojanov Risto, Serafimovski Todor, 1990: The volcanism in the Zletovo–Kratovo volcanic area. In: "XII Congress of Geologists in Yugoslavia", Ohrid, 405–124.

Books:

(Boev, 1996): Boev Blažo, Janković S., 1996: *Nickel and nickel-ferrous iron deposits of the Vardar zone (SE Europe) with particular reference to the Ržanovo–Studena Voda ore bearing series*. Faculty of Mining and Geology, Spec. Iss. No. **3,** pp. 273.

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