

НАУЧНО-ТЕХНИЧЕСКИ СЪЮЗ ПО МИННО ДЕЛО, ГЕОЛОГИЯ И МЕТАЛУРГИЯ
SCIENTIFIC AND TECHNICAL UNION OF MINING, GEOLOGY AND METALLURGY
НАУЧНО-ТЕХНИЧЕСКИЙ СОЮЗ ПО ГОРНОМУ ДЕЛУ, ГЕОЛОГИИ И МЕТАЛЛУРГИИ



PROCEEDINGS

of the

XII INTERNATIONAL GEOMECHANICS CONFERENCE

7 – 11 September 2026
Astor Garden Hotel, Sts. Constantine and Helena
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Proceedings of the XII INTERNATIONAL GEOMECHANICS CONFERENCE



**7 – 11 September 2026
Varna, Bulgaria**

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***Dear Ladies and Gentlemen,
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Dear Guests,***

I am pleased on behalf of the Organizing Committee to congratulate the participants in the **XII International Geomechanics Conference**.

This year's edition of the conference is the twelfth, and the conference has been held for more than 27 years, which proves the authority and significance of this scientific forum. The theme of the conference this year is **"Geomechanics in a Changing Engineering Environment"**.

The conference topics include the entire spectrum of fundamental issues related to the physical and mechanical properties of rocks and soils, the stress-strain state of rock massifs and soils, measurements in geomechanics and remote methods, stability assessment, blasting and seismic impacts, dynamic manifestations of rock pressure, ecology and environmental protection, and artificial intelligence. This actual thematic topics provoked your interest again and we suggest to your attention these scientific papers, presented on the conference.

I would like to express my sincere gratitude to the Golden Sponsor Geotechmin Group - Geotechmin OOD, Ellatzite-Med AD, Geotrading AD, Geostroy AD and Silver Sponsor - Assarel Medet AD.

The discussion of research results during the conference will provide opportunities for the application of geomechanical methods related to the development and use of underground space in the mining industry, construction, industrial and public buildings, transport facilities, and others.

We look forward to meeting you at the **XIII International Geomechanics Conference!**

Be healthy and good luck!

**Assoc. Prof. Dr. Eng. Kremena Dedelyanova
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НА НАУЧНО-ТЕХНИЧЕСКИТЕ
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TOPIC A

Physical and mechanical properties of rocks and soils

Физико-механични свойства на скали и почви



PHYSICAL - MECHANICAL CHARACTERISTICS OF SECONDARY QUARTZITES FROM THE LOCALITY "CRN VRV" AS A MATERIAL FOR ROAD TAMPON

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ABSTRACT

The paper presents the physical and mechanical characteristics of secondary quartzites from the "Crn Vrv" locality, which is located southwest of Kratovo, in the Kratovo-Zletovo volcanic area, Republic of North Macedonia.

Secondary quartzites or silexes are a product of hydrothermal alterations in rocks of intermediate composition (andesites, andesitic tuffs and breccias).

The examination of the physical and mechanical characteristics of the material, its chemical composition, as well as special analyses of the crushed material, showed that the material can be used in construction as a tampon material for roads and also as an aggregate for mineral mixtures of concrete.

Keywords: Quartzites, tampon material, physical and mechanical characteristics, chemical composition.

Introduction

Within the volcanic rock complex, in the Kratovo-Zletovo volcanic area, in NE Macedonia, several localities are known in which significant masses of strongly silicified rocks are encountered, extending from the extreme NW part of this area: near the village of Beljakovci, Sopsko Rudari, and across the hills: Borovik, Cmi Vrv, Plavica and Ozren, to the village of Tursko Rudari and Spancevo, in its extreme SE part. In addition to the aforementioned, strongly silicified rocks are also present in other localities in this area, but there they occur in smaller concentrations and with lower intensity.

Although these rocks were formed as a result of hydrothermal silicification /in a broader sense/, they are not uniform, they differ significantly from each other, both in terms of composition and in terms of physical and mechanical characteristics. Specific and particularly favorable chemical, mineralogical-petrographic and physical and mechanical characteristics are possessed by the siliceous hydrothermal rocks in the central part of the Kratovo-Zletovo volcanic area /in the vicinity of Kratovo/, especially on the Plavica and Cmi Vrv mountains. The Plavica and Crn Vrv mountains represent the extreme western parts of the Osogovo massif, and are located about 7 km SE (Crn Vrv) and 3 km south (Plavica) of Kratovo, and at a distance of about 5 km from each other.

In the geological literature, these rocks are known under several different names, such as: silex, secondary quartzites, metasomatic quartzites, orthoquartzites, hydrothermal quartzites - hydroquartzites, alumoquartzites, monoquartzites, kazakhites, secondary alumoquartzites, etc. In our geological literature, these rocks are most often referred to as "secondary quartzites". This term refers to the products of hydrothermal alterations of the rocks in the volcanic apparatuses, which are formed in the stage of calming down of volcanic activity and which are naturally found in the complex characterized by the constant presence of quartz (partially chalcedony and opal) and a certain amount of impurities from other minerals. However, in our professional, especially commercial terminology, this specific mineral raw material has been known for a long time under the name - silex.

. Secondary quartzites (silex) as mineral raw material have large uses in ceramic and similar industries for coating grinding mills, in abrasive industry for production of flint – paper, as "sand" for cutting decorative stones, as material for making containers for aggressive chemicals, in electrical – chemical industry for obtaining ferro – silica or silica metal. For all these products can be used only high quality silexes which beside favorable chemical composition should have favorable physical – mechanical properties, and such are those in the "Crni Vrv" deposit, which have been exploited for several decades.

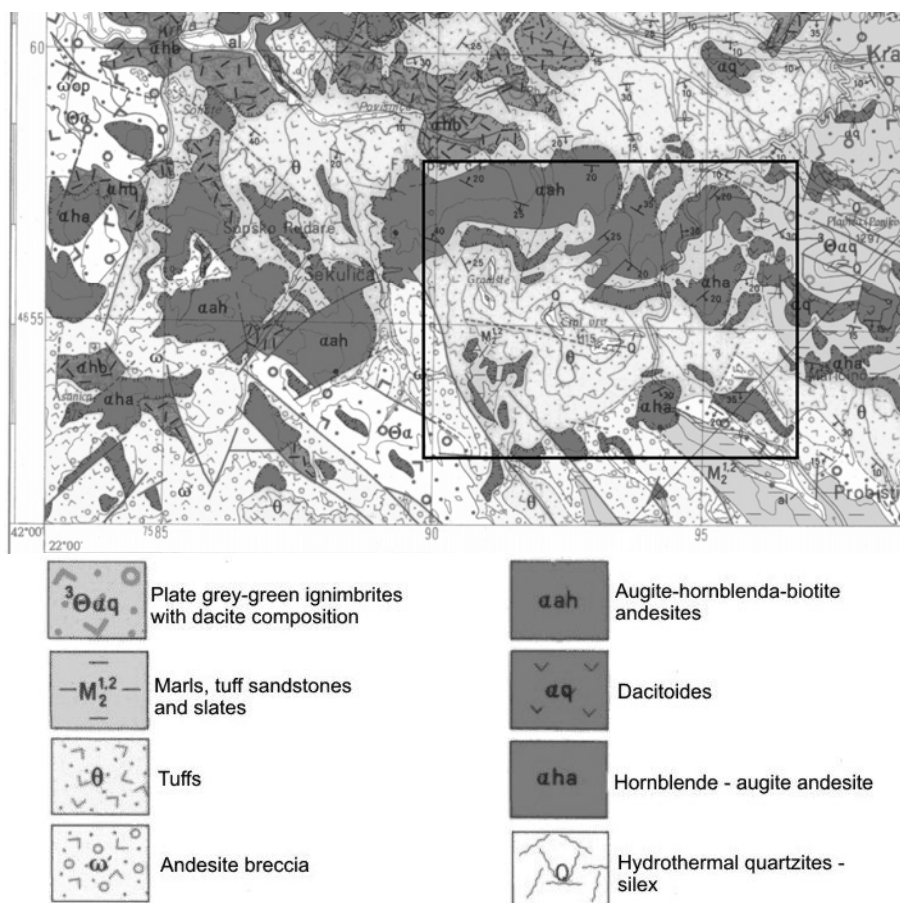


Fig. 2: Geological map of the vicinity of the investigated area [1, 2]

Geological features of the deposit

The area of the central part of the Kratovo - Zletovo volcanic area, in which the "Crni Vrv" deposit is located, is composed of a complex of volcanic, subvolcanic and volcanogenic-sedimentary formations, the composition of which corresponds to a granodioritic magma, or its equivalents - dacites and andesites.

The petrographic composition of the rocks represented here is quite heterogeneous, considering that here occur rocks with a composition close to rhyolites (quartzlatites) and those with a composition close to basalts (andesite – basalts), so we could speak of an association: rhyolite – dacite – andesite - basalt, with numerous, often unclear transitions between them, going from the most acidic to the most basic representatives, or vice versa. Here, it is possible to distinguish three phases of the formation of the volcanics: the first phase includes amphibole - biotite and pyroxene - biotite acito - andesites; the second phase is subvolcanic hardened sanidine dacites (quartzlatite) and on the third, last phase occurred outcrops of labradorite - augite andesites (andesite basalts).

Pyroclastic rocks are formed, for the most part, in the first phase, but their formation continues until the final phase of volcanic formation.

Volcanism in the central part of the Kratovo-Zletovo region was predominantly submarine and sublacustrine and intense over a relatively long geological period (from the Middle Oligocene to the beginning of the Quaternary), which is evidenced, among other things, by the great thickness of the volcanic complex of the rocks. The occasional phases of subsidence of volcanic activity correspond to the deposition of volcanogenic-sedimentary formations. The thickness of the volcanic complex of the rocks, i.e. the depth at which their crystalline or plutonic foundation is found, has not yet been determined by the research work carried out so far, but it is certain that in this part of the Kratovo-Zletovo volcanic region it exceeds 1,000 m.

Secondary quartzites occur in andesitic-dacite rocks along a fault line that has a regional character. It

extends in the direction NW - SE starting from Kumanovo through Crni Vrv, Plavica - Zlatica, Pleshinci to Probishtip. Along these fault structures, siliceous components were deposited from hydrothermal solutions that underwent intensive metasomatic changes in the surrounding volcanic rocks, forming large masses of silicified rocks. In the area of the deposit itself, the fracture systems occur as ring-shaped forms where the hydrothermal-metasomatic processes are most pronounced. In addition to dacite-andesitic rocks, andesitic tuffs and breccias are found that have undergone a lower degree of silicification or are not silicified at all.

Secondary quartzites occur at the surface and, with small interruptions, can be traced over 2 km. Their thickness is quite variable and ranges from 20 – 80 m, and gradually decreases with depth (fig. 3).

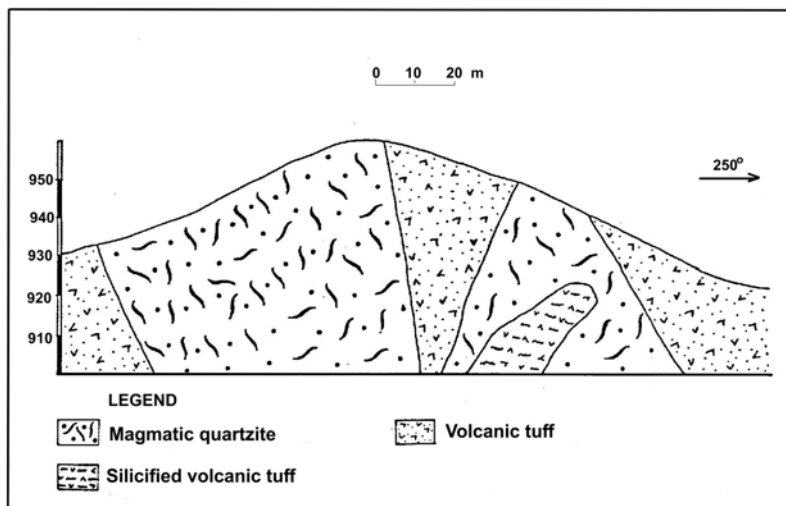


Fig. 3. Geological profile of the deposit "Crni Vrv" [3]

The genesis of secondary quartzite from "Crni Vrv" is closely related to the hydrothermal changes of rocks of intermediate composition, in volcanic apparatuses and their immediate surroundings. Their formation begins after the paroxysmal activity of the volcanic apparatus, i.e. in the fumarolic - solfatar stage. The fumarolic-solfatar alterations take place not only along the cracks, but especially along the horizons of the porous products of the eruptions, which can be spread over several hundred meters from these apparatuses [3, 4].

Accordingly, secondary quartzites are metasomatic formations that formed, basically, without the introduction of SiO_2 , from the magma (also Al_2O_3 , TiO_2 , K_2O and Fe), which indicates that only the redeposition of these components and their transfer to the location of the action of gas hydrothermal solutions. Only water, S, F, Cl, P, B and heavy metals (except Fe) were brought. This is evidenced by the preserved relict structures and textures of the original rocks in them, as well as their spatial position. Namely, the siliceous ore bodies have a subvertical distribution, and their dimensions gradually decrease with depth. Data from deep exploration drillings show that their roots are found at a depth of over 400 m, when they gradually emerge. Their borders towards the surrounding volcanic rocks are most often gradual, i.e. the degree of silicification of the surrounding rocks gradually decreases with distance from the pure siliceous masses (with over 95 % SiO_2).

Mineralogical, petrographical and chemical composition of quartzites

The secondary quartzite ore bodies of Crni Vrv are made of amorphous to microcrystalline silica mass, sometimes with some opal. Their color is light gray to slightly blue, and when brecciated, reddish. These are dense, very hard and tough rocks, very difficult to process, resistant to impact and abrasion, with low porosity and high resistance to the action of aggressive chemicals. They have a regularly high content of silicate minerals (which significantly distinguishes them from other types of secondary quartzites) and a tolerant content of harmful components. An "average sample" of quality quartzite from the "Crni Vrv" deposit has the

following chemical composition (%) [3]:

Table 1. Chemical composition of quartzites

SiO₂	98.23	MgO	0.025
TiO₂	0.20	CaO	0.15
Al₂O₃	0.35	Na₂O	0.008
Fe₂O₃	0.32	K₂O	0.10
FeO	0.15	P₂O₅	Traces
MnO	traces	Loss of ignition	0.47

Physical - mechanical parameters of quartzite

The physical – mechanical properties of quartzite are determined with several laboratory examinations on tampon quartzite material with grain size from 0 to 31.5 mm.

Table 2 shows the results obtained from the geomechanical examinations: [5]

Table 2. Physical - mechanical characteristics of quartzite

Test	Results	Criterion
Grain shape (% mass)	14.54	(max) 40 %
Dilapidated grains	1.09	(max) 7 %
Content of clay and silt particles (% mass)	1.64	(max) 5 %
Sensitivity on ice influence (content of particles < 0.02 mm)	2.11 (F1)	/
Consistency on ice Na ₂ SO ₄ (loss of mass)	grains < 8 mm – 3.9 % grains > 8 mm – 3.5 %	grains < 8 mm to 10 % grains > 8 mm to 12 %
Optimal water content / Maximum volume mass – Proctor test (modified method)	$\gamma_{dmax} = 2.06 \text{ g/cm}^3$ $W_{opt} = 5.7 \%$	/
Granular composition	There is no deviation from the boundary belt for the tampon material	Boundary belt for the tampon material
Degree of unevenness	34.0	(min) 15.0
Abrasion loss value by Los Angeles method (% mass)	21.8	(max) 40 %
California bearing ratio (CBR) %	81.4	(min) 80 %
Determined organic matters	0.81	(max) 5 %
Hardness after Moss	7	
Compressive Strength (MPa)	150-300	
Compressive Strength (MPa)	150-300	
Compressive Strength (MPa)	150-300	
Porosity	3.56 %	
Specific mass	2.63 – 2.70 t/m ³	
Volume mass	2.51 - 2.64 t/m ³	

Conclusion

The investigations conducted on the secondary quartzites (silexes) from the "Crn Vrv" locality confirmed that this material possesses highly favorable physical, mechanical, and chemical characteristics for application in road construction. The geological and mineralogical analyses indicate that these hydrothermally altered



quartzites are characterized by a very high silica content (98.23% SiO_2), low porosity, high hardness, and excellent resistance to mechanical wear and weathering.

The laboratory test results demonstrate that all examined parameters satisfy the prescribed requirements for road tampon materials. The aggregate exhibits a suitable grain shape, very low content of clay and deleterious particles, excellent resistance to frost action and abrasion, high California Bearing Ratio (CBR), and appropriate compaction characteristics. Furthermore, the granulometric composition falls within the required limits for road base construction.

The obtained results confirm that the secondary quartzites from the "Crn Vrv" deposit represent a high-quality construction material suitable for use as road tampon material and, owing to their favorable properties, also as aggregate for concrete mineral mixtures. Their utilization provides a reliable and durable source of construction aggregate while promoting the efficient exploitation of domestic mineral resources. Consequently, the "Crn Vrv" quartzites represent a valuable raw material with significant technical and economic potential for infrastructure development in North Macedonia.

References

1. Hristov S. et al. (1963 - 1968). Basic geological map of the Republic of Macedonia - sheet Kratovo 1 : 100 000
2. Hristov S. et al. (1969). Interpreter of Basic geological map of the Republic of Macedonia - sheet Kratovo 1 : 100 000;
3. Blazev, K. et al. (2009). Mining project for exploitation of Quartzite from the Kratovo – Zletovo area, Probishtip
4. Panov, Z. (2011). Rock mechanics. University textbook. Stip
5. Geing – Krebs und Kiefer (2017). Report from examinations of geomechanical characteristics of quartzite – 0/31.5 mm for evaluation for its use as tampon