PROCEEDINGS

OF THE XIV INTERNATIONAL CONFERENCE OF THE OPEN AND UNDERWATER MINING OF MINERALS

July 3 – 7, 2017
International House of Scientists "Fr. J. Curie"
Varna, Bulgaria

SCIENTIFIC AND TECHNICAL UNION OF MINING, GEOLOGY AND METALLURGY
ISSN: 2535-0854
2017, Bulgaria

If you are interested in purchasing a copy of this book, please:
Telephone/Fax ++359 2 986 13 79, E-mail: mdgm@fnts.bg

By courtesy of

FEDERATION OF THE SCIENTIFIC ENGINEERING UNIONS

WITH COOPERATION

- Ministry of Economy in Bulgaria
- Ministry of Energy in Bulgaria
- Ministry of Environment and Water in Bulgaria

CO-ORGANIZERS

- University of mining and geology “St. Ivan Rilski”
- University of Architecture, Civil Engineering and Geodesy
- Higher School of Civil Engineering “Lyuben Karavelov”
- University of Transport “Todor Kableshkov”
- Bulgarian chamber of mining and geology
- Bulgarian construction chamber
- Association “Bulgarian coal mining”

PARTNERS

- “Andezit” Ltd.
- “Andela” JSC
- “Assarel Medet” JSC
- “Atlas Copco Bulgaria” Ltd
- “BT engineering” Ltd.
- “Bumar” JSC
- “Vatija” JSC
- “Geotechmin” Ltd.
- "Dundee Precious Metals Krumovgrad" EAD
- “Ellatzite-med” JSC
- “Eskana” JSC
- “Zlatna Panega Cement” JSC
- “Kaolin” JSC
- MDZ “Balsha” JSC
- “Minproekt” JSC
- “Minstroy Holding” JSC
- “Beli breg” mine JSC
- “Stanyantzi” mine JSC
- “Bobov dol” mine JSC
- “Marica Iztok” mines JSC
- Open pit Coal Mining – Pernik
- “Niproruda” JSC
- “Sanrock” Lrd.
- “Hemus – M” JSC
- “Holcim Karierni Materiali” AD

WITH MEDIA PARTNERS

- Journal "Mining and geology"
- Journal "Geology and mineral resources"
- Newspaper "Rudnichar"
- Publishing house "Ore and metals"
- Newspaper "Science and society"

ORGANIZING COMMITTEE

Chairman:	
Prof. Dr. Tzolo Voutov	Chairman, Scientific and technical union of mining, geology and metallurgy
Honorary Chairman:	
Prof. DSc Stoyan Hristov	University of mining and geology “St. Ivan Rilski”
Deputy Chairmen:	
Prof. Dr. Lachezar Tzotzorkov	Chairman, Bulgarian chamber of mining and geology
Prof. Dr. Lyuben Totev	Rector, University of mining and geology “St. Ivan Rilski”
MSc. Eng. Andon Andonov	General manager, Maritza Iztok Mines JSC
Scientific secretaries:	
Dr. Eng. Kremena Dedelyanova	Secretary general, Scientific and technical union of mining, geology
Dr. Eng. Konstantin Georgiev	Honorary member of the ISM
Organizers:	
Dr. Krassimira Arsova	Scientific and technical union of mining, geology and metallurgy
Dr. Julian Dimitrov	University of mining and geology “St. Ivan Rilski”
Members:	
Assoc. Prof. Dr. Anatolii Angelov	University of mining and geology “St. Ivan Rilski”
Andreas Ispiridis	“Hemus – M” JSC
MSc. Eng. Andrian Valchev	“Kaolin” JSC
Prof. Dr. Valentin Velev	University of mining and geology “St. Ivan Rilski”
Dr. Eng. Vladimir Genevski	Scientific and technical union of mining, geology and metallurgy
Prof. Dr. Georgi Konstantinov	University of mining and geology “St. Ivan Rilski”
MSc. Eng. Dancho Todorov	“NIPRORUDA” JSC
MSc. Eng. Delcho Nikolov	“Assarel Medet” JSC
Prof. Dr. Dimitar Anastasov	University of mining and geology “St. Ivan Rilski”
MSc. Eng. Dimitar Tzotzorkov	“Bulteh” Ltd.
MSc. Eng. Dimitar Cholakov	“Maritza Iztok Mines” JSC
Prof. DSc Dimcho Jossifov	Scientific and technical union of mining, geology and metallurgy
MSc. Eng. Dobri Tzvetkov	“Ellatzite-med” JSC
MSc. Eng. Dragomir Draganov	“Ellatzite-med” JSC
Assoc. Prof. Dr. Ivaylo Koprev	University of mining and geology “St. Ivan Rilski”
MSc. Eng. Ivan Bogdanov	MDZ “Balsha” JSC
Prof. DSc Ivan Lalov	University of mining and geology “St. Ivan Rilski”
Assoc. Prof. Dr. Iliyan Djobov	University of mining and geology “St. Ivan Rilski”
Iliyan Rangelov	“Belaz-Sofia” Ltd.
Assoc. Prof. Kiril Chobanov	“Geotechmin” Ltd
MSc. Eng. Kostadin Naydenov	“Ellatzite-med” JSC
Dr. Eng. Krasimir Karparov	“Assarel Medet” JSC
Assoc. Prof. Dr. Nikola Dobrev	“KCM 2000” JSC
Prof. DSc Nikolay Valkanov	“Minstroy holding” JSC
Assoc. Prof. Dr. Pavel Pavlov	University of mining and geology “St. Ivan Rilski”
Prof. Dr. Petko Dimitrov	Institute of oceanology, Bulgarian academy of sciences
Prof. Dr. Petar Daskalov	Scientific and technical union of mining, geology and metallurgy
Assoc. Prof. Dr. Stanislav Topalov	Association “Bulgarian coal mining”
MSc. Eng. Stoyo Bosnev	“MINPROEKT” JSC
MSc. Eng. Tanyo Staykovski	“Georadar” Ltd.
Dr. Eng. Todor Tzonkov	“Andezit” Ltd
MSc. Eng. Huben Hubenov	“MINPROEKT” JSC
MSc. Eng. Shteryo Shterev	Scientific and technical union of mining, geology and metallurgy

INTERNATIONAL SCIENTIFIC COMMITTEE

THEMATIC TOPICS

A. New technologies and systems for open and underwater development of mineral deposits.
Нови технологии и системи за открито и подводно разработване на находища на полезни изкопаеми

B. Drilling and blasting activities and blasting materials.
Пробивно-взривни работи и средства за взривяване

C. Innovatios and quality management. Cost effectiveness.
Иновации и управление на качеството. Икономическа ефективност

D. Electrification, automation, mechanization and repair.
Електрификация, автоматизация, механизация и ремонтна дейност

E. Information technology design, geological, mining and mine surveying.
Информационни технологии при проектиране, геологопроучвателни, маркшайдерски и минни дейности

F. Drainage, stability and consolidation of the slopes in open pits, quarries, dumps and tailings.
Отводняване, устойчивост и укрепване на откосите в открити рудници, кариери, насипища и хвостохранилища

G. Ecology, protection and reclamation of environment.
Екология, опазване и възстановяване на природната среда

H. Technical safety in open pit and underwater mining of minerals.
Техническа безопасност при открит и подводен добив на полезни изкопаеми

PHYSICAL AND MECHANICAL CHARACTERISTICS OF THE SECONDARY QUARTZITES FROM THE DEPOSIT PESHTER IN THE REPUBLIC OF MACEDONIA

Krsto Blazev[1], Blagica Doneva[1], Gorgi Dimov[1], Marjan Delipetrev[1], Todor Delipetrov[1], Zoran Panov[1]
[1]University of Goce Delcev, Faculty of natural and technical sciences, Stip, krsto.blazev@ugd.edu.mk

ABSTRACT
The secondary quartzites as a special type of magmatic quartzite, due to their great hardness and toughness are widely used in industry for the preparation of mineral raw materials for production of liners and grinding balls of mills. Also, they are used in electrometaliurgy for obtaining ferrous-silica alloys.
The deposit of these mineral raw materials Peshter is located in the eastern part of Macedonia, near the town Probishtip. This deposit is a result of the final phase of the silification of the volcanic tuffs from Kratovo - Zletovo volcanic area.
The paper presents the physical and mechanical parameters of the secondary quartzites such as: specific and volume mass, hardness, toughness, abrasion etc. Also presented is their chemical composition and geophysical characteristics.
Keywords: *secondary quartzite, physical characteristics, mechanical characteristics.*

Introduction

In the part of Eastern Macedonia, where the exploration terrain is located, geological composition of the terrain is very complex, from the aspect of lithology and tectonic. This part of the country, according the tectonic regionalization, belongs to Eastern Macedonian zone. It is located near the town Probishtip at the distance of about 3 km. Secondary quartzite is formed with silification of the acid and intermediary volcanic rocks. This process took part separately or together with sericitization and chloritization.

These rocks are composed of quartz and sericite, but also contain alunite, diaspore and other minerals. As secondary minerals in quartzites may appear corundum, topaz, tourmaline and rutile.

According the laboratory examinations ca be concluded that hydrothermal quartzite origin in the process of the hydrothermal metasomatism of the intermediary volcanic rocks. The process of metasomatism was very intensive and in some parts of the rocks the percentage of silica is up to 98 – 99 %. Silicon matter is presented with microcrystal quartz mass, and opal mass occurs in in a subordinate amount.

Origin of quartzite

The origin of the qurtzite (silex) is connected to the hydrothermal alterations of intermediate rocks in the volcanic apparatus and its surrounding. Its formation starts with the increasing intensity of the volcanic activity, i.e. in the fumarole – solfatara stadium. The alterations in this stadium are not only along the fissures, but especially along the horizons of porous products of the eruption, which can be spread on distance more than 100 m from the volcanic apparatus.

Thus, secondary quartzite is metasomatic formation which was formed without bringing SiO_2 from the magma, which means that was done redeposition of the components and their movement in the area with influence of gas hydrothermal fluids.

For the origin of the secondary quartzites witness relic structures and textures of the mother rocks in them, and, also, their sub-vertical spreading. In depth, their dimensions gradually decrease. The borders with the surrounding volcanic rocks are gradual, i.e. gradually decreases the degree of silification of the surrounding rocks distancing from the secondary quartzite rocks.

Geological and tectonic features of quartzite

Geology

The immediate vicinity of the deposit Peshter is composed of Miocene, Pliocene and Pleistocene (Quaternary) rocks. Miocene rocks are represented with: plated grey - greenish ignimbrites of dacite composition (Θαq) and marls, tuff sandstones and slates ($M_1^{1,2}$). [1, 2]

- Plated grey - greenish ignimbrites of dacite composition (Θαq) represent small erosional zones along the ridges above the ignimbrites. They are composed of small phenocrystals (< 1 cm) which are altered more than the basis.

- Marls, tuff sandstones and slates ($M_1^{1,2}$) are determined western of Probishtip and they lay above the ignimbrites of dacite composition and below the tuffs and breccias. They are represented with marls, sandstones, tuff sandstones and slates. All of them are hydrothermally altered.

Pliocene sediments are represented by tuffs (Θ), andesite breccias (ω), augite – hornblende – biotite andesites (αah) and dacitoides (αq).

-Tuffs (Θ) are the most present rocks on the terrain and represent the basis of the younger effusive complex of the Kratovo – Zletovo volcanic area. They have grey, grey – yellowish, pinkish and green color and are very altered. Their average thickness is about 300 m.

- Andesite breccias (ω) lay above the older sediment and metamorphic rocks. The most present are western of Probishtip. They are composed of unprocessed pieces of andesite cemented with tuff material. Their thickness is about 200 m.

- Augite – hornblende – biotite andesites (αah) appear in andesite breccias as plates and masses. Rarely intruded the older rocks. They are composed of plagioclases, pyroxene – augite, hornblende and biotite. All minerals are altered and appear secondary quartz, sericite, calcite etc.

- Dacitoides (αq) are determined as protrusions on many places. They are hydrothermally altered: silicified, pyritized and limonitized. Dacitoides protrude the Tertiary sedimentary rocks, tuffs and breccias.

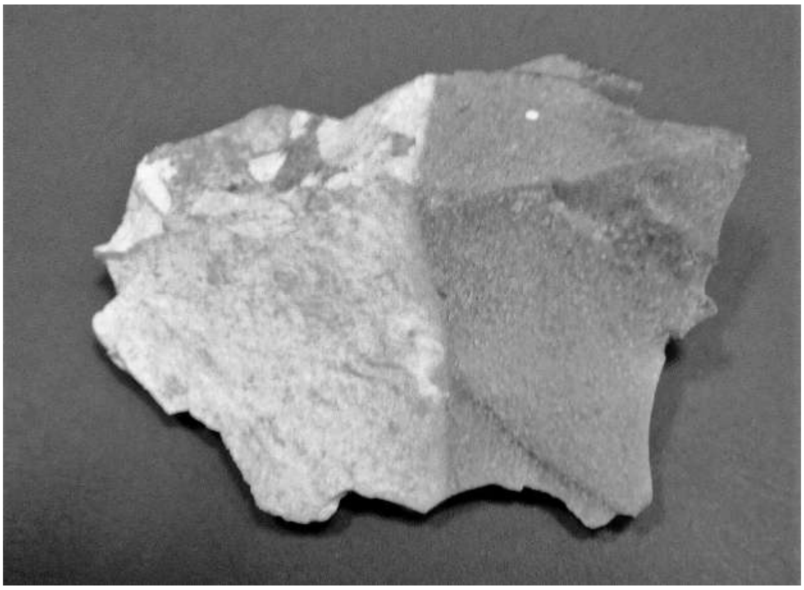

Fig. 1. Quartzite from the deposit Peshter

Pleistocene sediments are represented with hornblende – augite andesites (αha) and hydrothermal quartzites - silex (Q).

- Hornblende – augite andesites (αha) lay above the ignimbrites of andesite composition and other older volcanic rocks. They are very tough fine grained rocks with dark green to black color. In the basic mass are present phenocrystals of plagioclases and hypidiomorphic grains of augite, hornblende and fresh biotite.

- Xydrothermal quartzites - silex (Q) are the most present on the mountain Crn Vrv. They appear as larger plates above the volcanic rocks. According their composition and way of occurence, quartzites are determined of hydrothermal origin. The color is variable: from grey – white, yellow to red, depending of the content of metal wires.

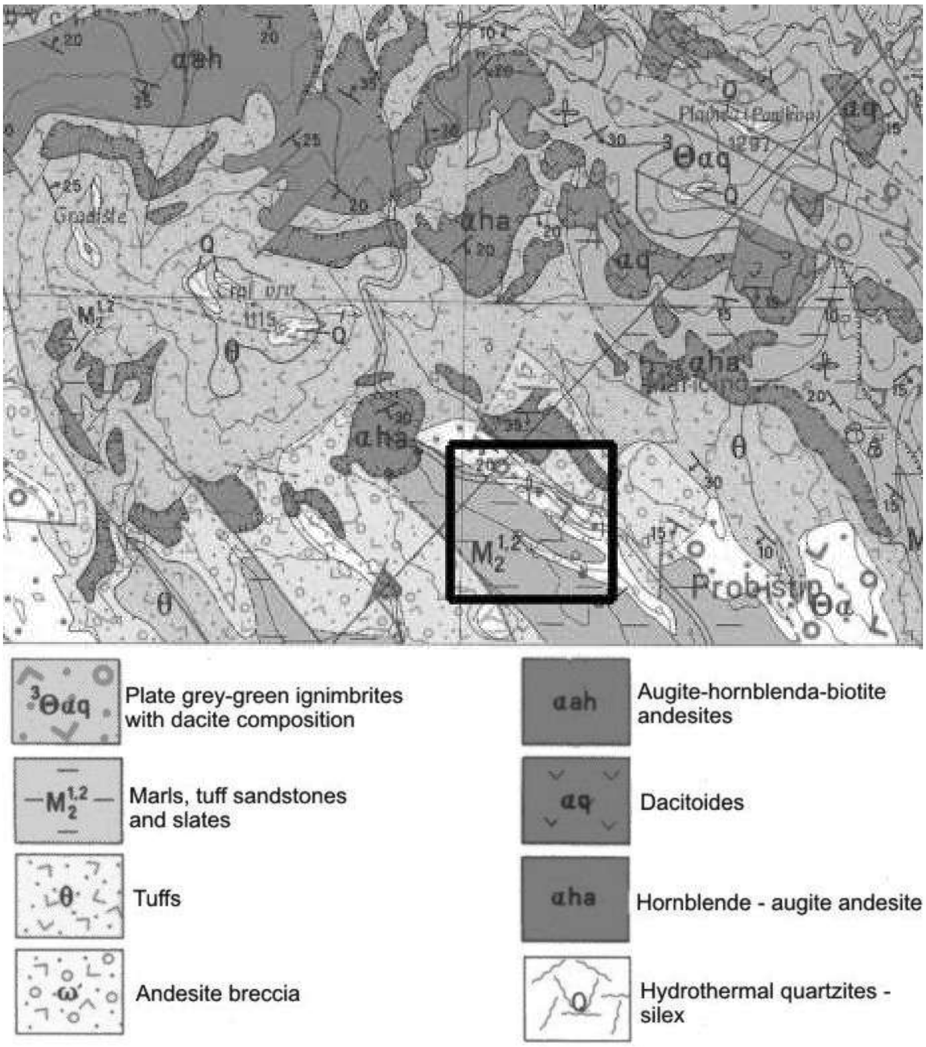

Fig.2: Geological map of the investigation area [1, 2]

Tectonics

Investigated area belongs to Kratovo - Zletovo volcanic area and there are determined faults of the three systems. The system of faults with orientation NNW - SSE are the most present, while the other two types of faults with orientation N - S and SE - NW are less present on the terrain. Those are disjunctive systems reflected from the first structural stage, or from the crystal basis of Serbian – Macedonian mass above which lay volcanic rocks. Beside disjunctive tectonic forms, in the wider vicinity are present plicative tectonic structures with poorly expressed synclines and anticlines.

Chemical, physical and geophysical parameters of quartzite

Examinations of this mineral raw material showed that there are two types of quartzites. One is with better quality and composed of microscopic fine quartz as main component, and the other type contains relics from the mother rocks - tuffs and has lower quality.

Examinations from chemical aspect showed that quartzite has the following average composition: [3]

Table 1. Chemical composition of quartzite

SiO_2	96,57 %
Fe_2O_3	0,46 %
Al_2O_3	0,38 %
CaO	0,16 %
MgO	0,28 %
Na_2O	0,016 %
K_2O	0,013 %

In addition to chemical examinations, mineral composition of the rock is determined with XRD method. Diffractogram is presented on Fig. 3

X – ray examinations were made with X – ray diffractometer Shimadzu 6100. Conditions for recording were: Cukα – radiation, voltage of the tube and the current are 40 (KV) and 30 (mA), θ-2θ=2-40°, speed (degree/minute) 2.00/0.100, time - 0.12 seconds.

Based on the peak position, and according the angle 2Θ is made identification of the minerals, and based on the peak intensities is concluded their relative quantity in the sample.

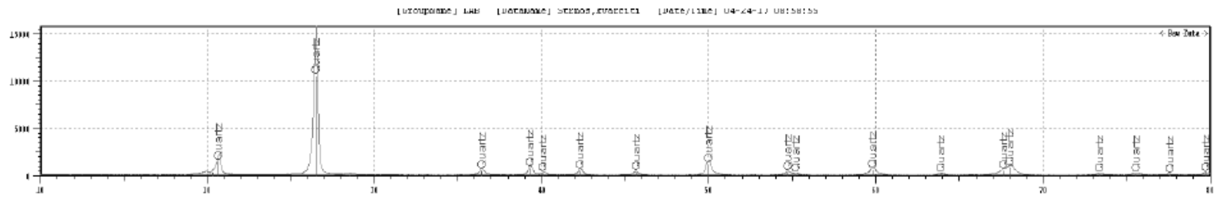

Fig. 3. X-ray diffractogram of quartzite

The obtained d – values and intensities (I) from the diffractogram on the fig. 3 were compared with the corresponding data from JCPDS cards.

From the results is determined that in the sample is present only mineral quartz JCPDS 00 046 1045.

Conducted research for determination the quartzite density with analysis of samples from different locations showed that density varies within 2,32 - 2,42 g/cm^3.

Thermal characteristics of quartzite

Thermal properties of quartzite play an important role in geology. Specific heat capacity, resistance offered by the rock to heat, water, pressure etc. are some of the thermal properties of quartzite. [4]

Specific heat capacity is defined as the heat capacity per unit mass of rock. Specific heat capacity or specific heat is one of the important properties of quartzite and it amounts to 0.75 kJ/Kg K. Properties of quartzite also include resistance of quartzite to heat, water, pressure, impact etc. It helps in determining the parameters to which quartzite offers resistance. If we talk about quartzite resistance, quartzite is heat resistant, impact resistant, pressure resistant.

Electrical characteristics of quartzite

Conducted in situ investigations of geoelectrical aspect showed the following results: the specific electrical resistivity of quartzite is within the interval 1 x 10^3 - 2 x 10^6 Ω/m. [4]

Geoelectrical measurements were performed with Terrameter SAS 1000.

Geomechanical characteristics of quartzite

Physical properties of rocks are used to identify the type of rocks and to discover more about them. There are various physical properties of quartzite like hardness, grain size, fracture, streak, porosity, luster, strength etc which defines it. The physical properties of quartzite rock are vital in determining its quartzite texture and quartzite uses.

The physical properties of quartzite depend on its formation. Physical properties of rocks play an important role in determining its applications in various fields. Rocks are rated on the on the Moh's Hardness Scale which rates the rocks on the scale from 1 to 10. The hardness of quartzite is about 7 to 7.5 whereas its compressive strength is 115.00 N/mm^2. Streak is the color of rock when it is crushed or powdered. The streak of quartzite is white whereas its fracture is uneven, splintery or conchoidal. Luster of quartzite is the interaction of light with the surface of quartzite and it is vitreous. Quartzite cleavage is indiscernible. The specific gravity of quartzite is 2.6-2.8. Quartzite is transparent to translucent in nature whereas its toughness is 1.9.

From the deposit Pester are taken more samples of the outcrop and of other investigations (boreholes, digs and cut section) to determine the physical and mechanical characteristics of this rock. But the necessary tests were not performed and in the paper are presented experiential data from similar materials.

The physical properties of quartzite are given in Table 2, and the strength is given in Table 3. [5]

Table 2. Physical properties of quartzite

Hardness	7 – 7.5	**Luster**	Vitreous
Grain Size	Medium Grained	**Toughness**	1.9
Fracture	Uneven, Splintery or Conchoidal	**Specific Gravity**	2.6-2.8
Streak	White	**Transparency**	Transparent to Translucent
Porosity	0.1-0.5 %	**Density**	2.32-2.42 g/cm^3
Specific mass	2.63 – 2.70 t/m^3	**Abrasion**	0,065 kg/cm^3
Volume mass	2.51 - 2.64 t/m^3		

Table 3. Strength of quartzite (from Attewell & Farmer 1976) [6]

Rock	Compressive Strength (MPa)	Tensile Strength (MPa)	Shear Strength (MPa)
Quartzite	150-300	10-30	20-60

From the conducted field and laboratory examinations of the quartzite massif on locality Pester, we can separate crushing as a very important geomechanical characteristic of quartzite (table 4). [7]

Table 4. Coefficient of empirical criterion of fracture, according Hawk and Brown, 1980

Quartzite	Monolite without cracks **Q = 500** **RMR = 100**	Excelent quality, unchanged monolite **Q = 100** **RMR = 85**	Very good quality, cracks on 1 - 3 [m] **Q = 100** **RMR = 85**	Good quality, cracks on 0.5 - 1 [m] **Q = 1.0** **RMR = 44**	Poor quality, cracks on 30 - 50 [cm] **Q = 0.1** **RMR = 23**	Very poor quality, cracks on 1 - 5 [cm] **Q = 0.01** **RMR = 3**
	m = 15	m = 7.5	m = 1.5	m = 0.3	m = 0.08	m = 0.015

Conclusion

Secondary quartzites on the exploration locality were formed as result of hydrothermal silification. They are not uniform and differ in the composition and physical – mechanical properties. These rocks are known with many different names, such as silexes, secondary quartzites, metasomatic quartzites, hydro-quartzites etc.

Based on the conducted chemical analyses, quartzite contains: SiO_2 - 96,57 %, MgO - 0,28 %, Fe_2O_3 - 0,46 %, Na_2O - 0,016 %, Al_2O_3 - 0,38 %, K_2O - 0,013 %, CaO - 0,16 %.

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 chamical composition should have favorable physical – mechanical properties.

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 deposit Pester, Probishtip
4. Jakosky, J. (1965). Geophysical explorations, Scientific book, Belgrade
5. Archae Solenhofen (2003). Rock properties and their importance to stoneworking, carving, and lapidary working of rocks and minerals by the ancient Egyptians
6. Attewell, P.B. and Farmer, I.W. (1976) Principles of engineering geology. Chapman and Hall, London, 1045 p.
7. Panov, Z. (2011). Rock mechanics. University textbook. Stip