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MINERALS FROM MACEDONIA
XV. SIVEC MINERAL ASSEMBLAGE

Blažo Boev[1], Gligor Jovanovski[2], Petre Makreski[2], Vladimir Bermanec[3]

[1]*Department of Petrology, Mineralogy and Geochemistry, Faculty of Mining and Geology, "Ss. Cyril and Methodius" University, Goce Delčev 89, MK-2000 Štip, Republic of Macedonia*
[2]*Institute of Chemistry, Faculty of Science, "Ss. Cyril and Methodius" University, P. O. Box 162, MK-1001 Skopje, Republic of Macedonia*
[3]*Institute of Mineralogy and Petrology, Department of Geology, Faculty of Science, University of Zagreb, Horvatovac bb, HR-10000 Zagreb, Croatia*
bboev@rgf.ukim.edu.mk

A b s t r a c t: The paper presents investigations carried out on the collected minerals from the Sivec deposit. It is situated in the vicinity of the town of Prilep, representing a rare occurrence of sugary white dolomite marbles. The application of suitable methods of exploitation of decorative-dimension stones makes possible to obtain large amounts of commercial blocks well known in the world. Despite the existence of dolomite marbles, a series of exotic minerals are typical in Sivec mineralization. Among them, the most significant are: calcite, fluorite, rutile, phlogopite, corundum, diaspore, almandine, kosmatite (clintonite or margarite), clinochlore, muscovite, quartz, pyrite, tourmaline and zoisite. An attempt to identify ten collected minerals using the FT IR spectroscopy is performed. The identification of the minerals was based on the comparison of the infrared spectra of our specimens with the corresponding literature data for the mineral species originating all over the world. The coloured pictures of all studied silicate minerals are presented as well.

Key words: Sivec; Republic of Macedonia; mineral assemblage; FT IR spectra

INTRODUCTION

The interest on the investigation of the Sivec started long time ago when the first crystals of corundum and diaspore were found in the sugary white marbles (Erdmanndsdorffer, 1925). Defining the detailed mineral assemblage in the Sivec site was also the subject of investigation carried out by Barić (1960) with regard to the crystallographic features of corundum and diaspore. Since then, a number of studies have been carried out in order to connect the lithologic, structural, petrographic and mineralogical features of the white dolomite marbles in the vicinity of Prilep (Dumurdžanov et al. 1994) (Fig. 1).

Fig.1. Part of Sivec marbles deposit

GEOLOGICAL CHARACTERISTICS OF THE PELAGONIAN METAMORPHIC COMPLEX

The area of the Sivec decorative and technical stone exploitation and processing plant is situated in the Pelagon representing a large geologic-geotectonic unit in the Republic of Macedonia.

The major lithostratigraphic features of the Pelagon result from the primary accumulation of petitic-psamitic and carbonate sediments accompanied by poorly expressed initial magmatism. Over the Grenville orogenesis the complexes were affected by metamorphic-magmatic and tectonic processes when they metamorphosed into metamorphic rocks of epidote-amphibolite faces (Arsovski et al., 1977).

Present day understanding of the geological composition of the geological-geotectonic unit makes it possible to divide the complex into two parts: northern and southern.

The northern part is an asymmetric structure whose eastern portion is raised and contains gneiss and micaschist formations, whereas the formations of the so-called mixed series and the series of marbles have been found in the western portions of the segment. Plicative structures are mainly of west and northwest extensions.

The south part of the Pelagon is also asymmetrically built with uplift of the western wing where numerous plicative structures of submeridian direction that bend to the north and north-west.

The middle parts are built mainly of granidiorite masses so the part of the area is rather raised or deeply eroded. The transition from gneisses to marbles in the eastern margin of the Pelagon is gradual, with absence of micaschists and mixed series, which have been preserved only as relicts. There, the marble series in the eastern rim is present as a band with thickness almost twice smaller than that in the northern part (Arsovski et al, 1984).

The lithostratigraphic position of some formations differs from that of the formations in the northern part of the Pelagon.

LITHOSTRATIGRAPHIC CHARACTERISTICS OF THE NORTHERN PART OF THE PELAGON

Upper and lower parts have been distinguished in the northern part of the Pelagon in the Grenville metamorphic complex. The lower part is present as a series of gneisses and micaschists, whereas in the upper part a mixed series and a series of marbles have been determined. Besides, the lower part of the metamorphic complex is connected with granitoid bodies of the Prilep granitoids which in this part of the Pelagon are connected mainly with the terrains of Mt Babuna (Stojanov, 1968).

In the series of gneisses which make up the deepest parts of the Grenville metamorphic complex several litho-facial types have been distinguished: augen two-mica amygdaloidal, band like, leucocratic muscovite and epidote-muscovite-biotite gneisses.

Augen two-mica amygdaloidal gneisses are connected with the contact parts of the granitoid intrusions and gradually grade into two-mica biotite-muscovite gneisses.

In the lower parts, gneisses are massive and stratified, pseudolayered and schistose owing to the presence of mica. On the surface they erode into various irregular, oval shapes or sporadically there are half a meter thick gneiss arenite.

Gneisses are light red, so the portions that contain more quartz and feldspar-albite are brighter and those with more mica are grey-greenish.

As a rule, the lower parts of gneisses (presented as biotite muscovite gneisses) are characterized by prevalence of microcline, whereas in the upper parts albite and microcline are the most abundant. Porphyroblastic gneisses are closely related to the contact parts of the granites or the gneiss-granites in the valley of the river Babuna (at Teovo). The thickness of the gneiss series in the northern part of the Pelagon is estimated at 5 000 to 7 000 meters.

The series of micaschists is less widespread than the gneiss series. It was discovered at Plavenski Rid, Osoj and Silegarnik, Begovi Virovi and Kadino Pole, Ubava, north-west of the Kadina Reka basin and Mt Kitka. To the east of Prilep they were distinguished in Mts Prisoj, Viorila and some other places.

As a whole, the series of micaschists is present as micaschists, quartzites and graphite schists, which facially grade one into other both latterly and vertically.

Unlike gneisses, micaschists possess clearly pronounced dark brown to dark schistose texture depending on the graphite material in them. In addition to quartz, micaschists also contain micas (muscovite, biotite, paragonite), chlorite and garnets (of up to 30% in some parts), distene, staurolite, albite, amphibole, tourmaline etc. There are also garnet micaschists rich in garnet with crystals attaining several centimeters in size. They are abundant in Mt Viorila, north of Kozjak. Large distene crystals of 10 cm in size have been found in the micaschists in the area.

The mixed series in the north part of the Pelagon occupies a sequence of metamorphic rocks of variable petrographic composition: augen schists, feldspatised chlorite schists, cipolines, talc schists and marbles where rocks grade one into other both laterally and vertically. Of all lithological varieties gneisses (mainly albite) prevail (the area of Markova Reka, Kitka, Ruen, the village of Izvor etc). Metarhyolites are also present.

The marble series comprises the top parts of the Precambrian complex in the Pelagon. In the north, the series of marbles comprises the mountain masses of Jakupica, Karadžica and Dautica and the River Treska valley. Some areas north of Prilep (Sivec, Pletvar and Kozjak) are also made up of this carbonate formation. Relicts of it are present in the northern slopes of Kitka and in the eastern marginal part of the Pelagon (the village of Izvor, Veles).

The granitoid formation is less present in the north part of the Pelagon. It occurs as smaller granite bodies located in the gneiss and micaschists series. The bodies are 0.5 km^2 to several square kilometers in size. Larger granitoid bodies have been found in the north parts of Mt Babuna. Granodiorites prevail in the north, and granites are less present in the formation. A small diorite occurrence has also been found. Pegmatites, aplites and quartz veins occur as lode rocks.

LITHOSTRATIGRAPHIC FEATURES OF THE SOUTH PART OF THE PELAGON

The Precambrian metamorphic complex in the south part of the Pelagon extends south of the Pelagon to Mt Selečka, Dren, Nidže and Kajmakčalan. The complex is deeply eroded that can be seen from the metamorphic faces characteristic of the deeper parts of the amphibolite faces, then from the position of the micaschist series and the absence of mixed series. The Precambrian metamorphic complex was formed in conditions of regional metamorphism of pelite-psamite sediments, basic and acid volcanic intrusive rocks and carbonate rocks. The rocks are located in three lithostratigraphic levels: gneiss-micaschist series (lower metamorphic complex), mixed series and a series of marbles (Fig. 2).

The gneiss-micaschist series (gneisses and micaschists) comprises the lower stratigraphic level of the metamorphic complex and is made up of gneisses, micaschists, metadiabases, quartzites and granodiorites. Different temperature and pressure conditions during metamorphism, different levels and the influence of polyphase of granodiorite magmatism, resulted in zonar structure of the gneiss micaschist series. This made it possible to distinguish:

A lower zone present as homogenized mass, made up of muscovite-biotite gneisses, seldom amphibolite bands.

An upper zone, lithologically present as a fairly heterogeneous mass in which various types of gneisses, micaschists, amphibolites and quartzites alternate both vertically and horizontally.

The mixed series is well built and is present as a thick mass of layers in the north part of the Pelagonian massif. In the south the thickness of the massif decreases. Only partially preserved relicts of mixed series occur in the slope of the marble series.

The marble series is well preserved and has been found as a 1 500 to 2 000 meters thick mass in the margin of the south part of the Pelagon. It is transgressively overlain, with an angle discordance, by Riphean Cambrian low metamorphic rocks and Upper Cretaceous sediments that are characteristic of the Vardar Zone. At the Nidže-Labnica-Melnica-Veprčani-Belovodica strike the marble series is present as two superposition horizons. Dolomites and dolomite marble prevail in the lower horizon, whereas quartzite marbles in the upper.

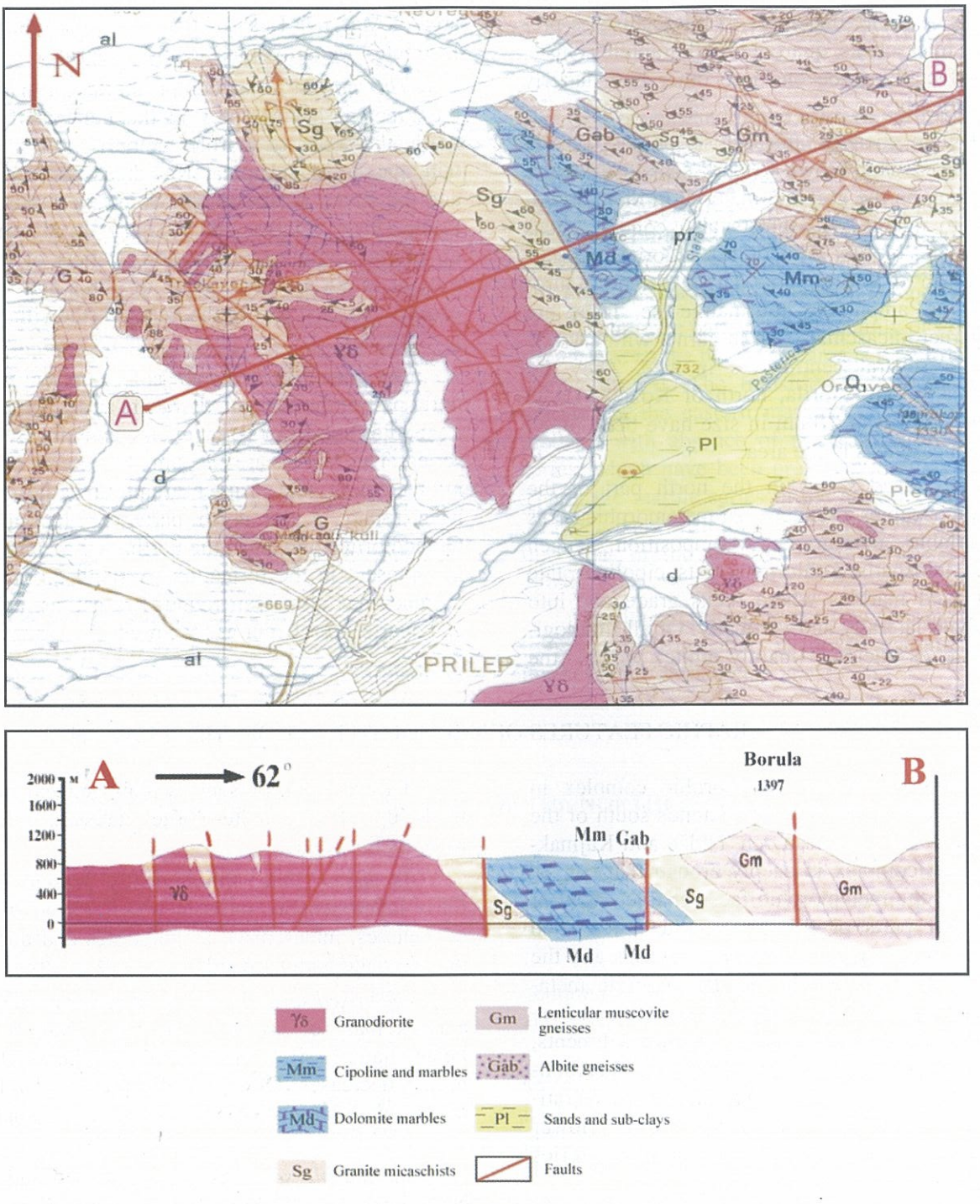


Fig. 2. Excerpt of the geological map of the Republic of Macedonia, scale 1 : 100 000

GEOLOGICAL CHARACTERISTICS OF THE SIVEC DEPOSIT

The marble in the Sivec deposit is part of the marble mass of the Pelagon. The mass is located between the Prilep anticline in the southwest and the Mukos intensely folded mountain massif in SE. To the NW it buries under Pliocene sediments of the periphery of the Pelagonian valley and emerges again at Cave and Kozjak syncline. The lithostratigraphic and tectonic characteristics of the marble mass indicate polyphase processes at the time of sedimentation, regional metamorphism and later tectonic deformations.

The essential structural characteristics of the metamorphic phase of the Pelagon are due to singenetic processes that took place during high regional metamorphism and folding with mechanism of flow and contemporaneous intrusion of first stage granodiorites when large folding structures were formed.

It should be mentioned that the second granitoid stage played an important role as well. It was the major magmatic activity whose products, in addition to the homogenization of the metamorphic rocks, refolded in some parts of the Pelagon and formed large folds causing destruction of those developed earlier. The entire area of Sivec has a syncline and an elongated structure that is in contact along a fault with the Derven anticline and Kozjak syncline.

The rocks of the mixed and marble series contributed to the formation of the Sivec syncline. The central parts of the series have been observed in the area of Crvenica. It is important to say that homogenization, whitening and dolomitization of marbles took place in the lower parts of the marble series. These processes are related to the intrusion of granitoid rocks in the Prilep anticline. Namely, the lower levels of the marble are made up of white sugary-white and massive dolomite marbles in which, only locally, traces of foliation and microfolding can be seen. Going further from the contact with the Prilep anticline to the east, dolomite marbles grade into ribbon-shaped and further on into schistose calcite-dolomite marbles.

Rupture tectonics present as faults, fault and fissure zones play and important role in the make up of the series. No doubt, some of the structures are older, but the major rupture zone is of later date and related to the formation of the neotectonic graben of the Pelagonian valley over the Pliocene.

In the SW the mass is distinguished as an important diagonal fault zone known as Nebregovo neotectonic fault along which low seismic quakes have been registered. This active fault structure of NW – SE strike and dip to south west under an angle of 60 – 80° crosscuts the marble mass at Sivec.

The second important periphery fault that confines the marble mass to SE is the covered fault that extends to NW-SE along the River Stara.

The extensive tectonics along these two faults resulted in fragmentation and the occurrence of smaller and larger fault and fissure systems. These essentially determine the manner of excavation of the marble masses in the site.

PETROGRAPHIC-MINERALOGICAL CHARACTERISTICS OF THE MARBLES IN SIVEC

The massive white and fine-grained marbles occur in the southwestern, whereas the dolomite-calcite marbles comprise the northeastern upper portions of the marble mass.

Microscopic studies carried out on samples of white fine-grained marbles taken also in the southwest part at the contact with gneisses determined that they possess fine-grained granoblastic structure with transitions to mosaic, sporadically porphyroblastic structure. In the broken parts, cataclastic structures, and at some places, milonite structures have been determined. Dolomite grains are from 0.1 to 0.5 mm in size. Dolomite grains are partially rounded with explicit cleavage. Sporadically they possess elliptical processes and are poorly elongated towards schistosity. Dolomite grains are seldom irregular up to polygonal in shape. Besides **dolomite** and **calcite**, the low amounts of **muscovite** also occur. It is of note that in the Sivec marble mass a series of exotic minerals such as **quartz**, **fluorite**, **rutile**, **phlogopite**, **corundum**, **diaspore**, **pyrite**, **tourmaline**, **zoisite**, **almandine**, **kosmatite** (**clintonite** or **margarite**) **and clinochlore** also occurs.

ASSEMBLAGE OF THE INDIVIDUAL TYPES OF MINERALIZATION IN THE SIVEC DEPOSIT

Collected minerals

1. Almandine, $Fe_3Al_2(SiO_4)_3$

Name origin:	After the locality *Alabanda* in Asia Minor
Crystal system:	Cubic (isometric)
Space group:	*Ia3d*
Unit cell parameters:	$a = 11.526$ Å , $Z = 8$

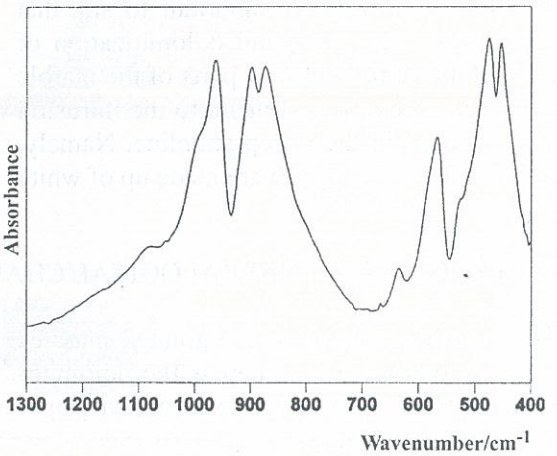
Color:	Brown, brownish red, red, black, black red
Hardness:	7–8
Density:	4.19 (exp.); 4.32 (calc.)
Cleavage:	None
Optical characteristics:	Isotropic, n = 1.77–1.82
Localities in Macedonia:	Prilepec, Štavica, Pelagon, Staro Bonče, Sivec

The crystals of almandine form dodecahedra, rhombdodecahedra or trepezohedra. The granular or compact masses are also found. They occur in chlorite schists, gneisses, mica schists and other metamorphic and pegmatitic rocks. Continuous solid solutions with its manganese analogue, spessartine are possible. Almandine has vitreous luster and white streak. It is used as a semiprecious gemstone.

The most beautiful almandine crystals in the Republic of Macedonia are found in the Pelagonian metamorphic complex, particularly in Mt. Selečka. Large almandine crystals (sometimes of enormous size) occur in the series of schists.

Mineral identification based on the IR spectral data given in: Ballaran et al., 1999; Farmer, 1974b; Geiger & Rossman, 1994; Hofmaister & Chopelas, 1991; Makreski et al., 2005; Moore et al., 1971; Nicodom, 1998; Omori, 1971.

Almandine from Sivec



FT IR spectrum of almandine

2. Calcite, $CaCO_3$

Name origin:	From the Latin *calx*, meaning *lime*
Crystal system:	Hexagonal (rhombohedral)
Space group:	$R\bar{3}c$
Unit cell parameters:	a = 4.989, c = 17.062 Å , Z = 6
Color:	Colorless, white, gray, yellowish white, reddish white and any other color (depending on the presence of impurities)
Hardness:	3
Density:	2.71 (exp.); 2.71 (calc.)
Cleavage:	{101} (rhombohedral) perfect
Optical characteristics:	Uniaxial(–), n_ω = 1.658 , n_ε = 1.486, δ = 0.172.

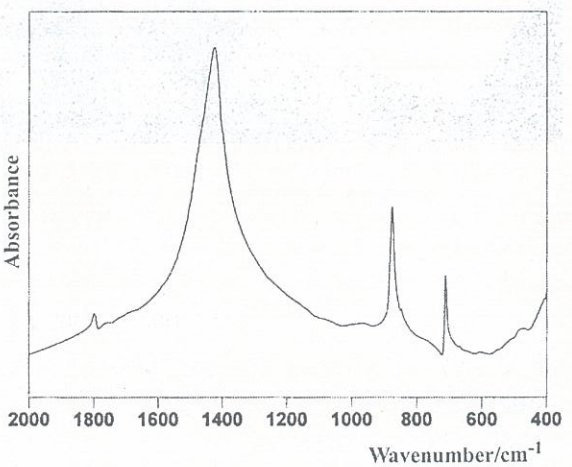
Localities in Macedonia: Alšar, Bešište, Bučim, Damjan, Mrzen, Nebregovo, Ržanovo, Sasa, Sivec, Trojaci

The hexagonal (rhombohedral) lower pressure polymorph of $CaCO_3$, calcite, is a very common and widespread mineral forming a variety of crystals. Mostly it occurs in the form of rhombohedron or scalenohedron. Their twinning is very common. Massive, fibrous, granular and stalactitic habits of calcite are also possible. Occuring in various parageneses, calcite may be magmatic, sedimentary, hydrothermal and metamorphic. It may be transparent to opaque with vitreous luster and white streak. Calcite mainly occurs as a main constituent of limestones and marbles. It may also be associated with diopside, garnet, epidote and other silicate minerals. Similarly to its polymorph aragonite, calcite is also constituent of the shells of some marine invertebrates. Calcite is extremely important industrial mineral being used as a raw material in the production of Portland cement, paper manufacture, steel industry, wastewater treatment, asphalt manufacture, suger refining, etc. Pulverized calcite is also used in pharmacy (e.g. to ward off the bone loss related to osteoporosis, to prepare various vitamin tablets, etc.). As a major constituent of marble, calcite is used in creation of various monuments.

Calcite is determined at several places in the Republic of Macedonia. It is of note that it occurs as various genetic types such as sedimentary-associated with travertine occurrences, metamorphic-associated with marble occurrences, hydrothermal – associated with hydrothermal occurrences of polymetallic mineralizations as well as a secondary mineral in ultrabasic rocks.

Mineral identification based on the IR spectral data given in: Jovanovski et al., 2002; Nicodom, 1998; White, 1974.

Calcite from Sivec



FT IR spectrum of calcite

3. Clinochlore, $(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$

Name origin:	From the Greek words *klino* (*κλίνω*) and *chloros* (*χλωρός*) meaning *oblique* and *green*, respectively
Crystal system:	Monoclinic
Space group:	*C2/m*
Unit cell parameters:	$a = 5.3$, $b = 9.3$, $c = 14.3$ Å, $\beta = 97°$, $Z = 2$
Color:	Blackish green, bluish green, white, yellowish green, olive green
Hardness:	2–2.5
Density:	2.65 (exp.); 2.83 (calc.)
Cleavage:	{001} perfect

Optical characteristics: Biaxial(+), n_α = 1.571–1.588, n_β = 1.571–1.589, n_γ = 1.576–1.599, δ = 0.0050–0.0110, $2V_z$ = 0–40°

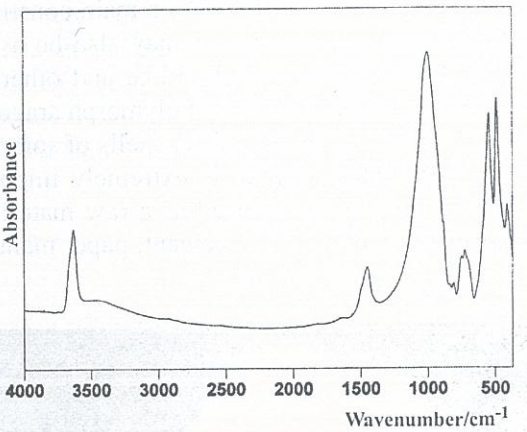
Localities in Macedonia: Sivec

Clinochlore crystallizes in the form of tabular crystals with the hexagonal cross-section. It may also be found in foliated, massive, granular, scaly or earthy habits. This mineral is transparent to opaque with colorless to greenish-white streak and vitreous to pearly luster. Clinochlore occurs in metamorphic rocks (usually schists) or as an alteration of hydrothermal minerals in igneous rocks.

In the series of dolomite marbles of Sivec there is an occurrence of greenish (about 2 cm large) clinochlore crystals. The clinochlore there is a part of the mineral assemblage consisting of corundum, phlogopite, rutile, muscovite, quartz, fluorite, clintonite etc.

Mineral identification based on the IR spectral data given in: Prieto et al., 1991; Smolander et al., 1989.

Clinochlore from Sivec



FT IR spectrum of clinochlore

4. Corundum, Al_2O_3

Name origin: Probably from the Sanskrit *kuruvinda*, meaning *ruby*

Crystal system: Hexagonal (rhombohedral)

Space group: *R*3*c*

Unit cell parameters: a = 4.751, c = 12.97 Å, Z = 6

Color: Red, blue, yellow, brown, gray

Hardness: 9

Density: 4.05 (exp.); 4.0 (calc.)

Cleavage: None

Optical characteristics: Uniaxial(–), n_ω = 1.768 , n_ε = 1.76, δ = 0.0080

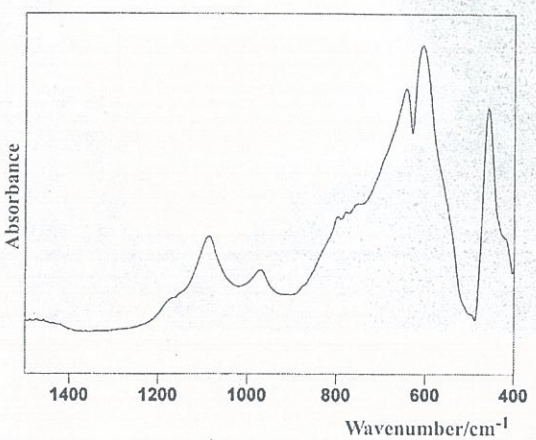
Localities in Macedonia: Sivec, Belo Pole, Nebregovo

Corundum is almost pure Al_2O_3. Its blue variety (sapphire) contains Fe and Ti, whereas the red colored corundum (ruby) contains Cr. This mineral forms prismatic, rhombohedral, tabular or bipyramidal crystals. Lamellar twins are common. It is transparent to translucent mineral with vitreous to adamantine luster and white colored streak. It occurs as an accessory mineral in limestones, dolomites, mica schists and gneisses. Corundum is associated with tourmaline, kyanite, hematite, magnetite, granates etc. The corundum varieties ruby and sapphire are used as gemstones. In some cases, the high-quality ruby is more valuable than diamond.

Corundum occurrence in the Republic of Macedonia is related to the dolomite marbles of Sivec near Prilep. There, corundum exceeds 20 cm in size. It is pinkish to red occurring in association with minerals such as diaspore, rutile, fluorite, calcite, dolomite, tourmaline, pyrite, chlorite, muscovite, distene.

Mineral identification based on the IR spectral data given in: Farmer 1974a; McDevitt & Baun, 1964; Nicodom, 1998; Plyusnina, 1977; Serna et al., 1982; Taylor et al., 1970.

Corundum from Sivec



FT IR spectrum of corundum

5. Diaspore, AlO(OH)

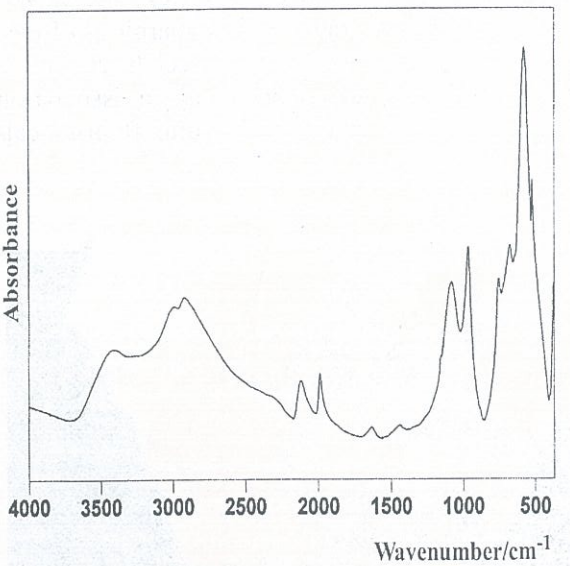
Name origin:	From the Greek word *diaspeirein* (*διασπείρειν*), meaning *to scatter*, referring to the mineral's easy disintegration in the blowpipe flame
Crystal system:	Orthorhombic
Space group:	*Pbnm*
Unit cell parameters:	$a = 4.397$, $b = 9.421$, $c = 2.8439$ Å, $Z = 4$
Color:	White, greenish gray, grayish brown, yellow, purple, pink, colorless.
Hardness:	6.5–7
Density:	3.4 (exp.); 3.38 (calc.)
Cleavage:	{010} perfect, {110} good
Optical characteristics:	Biaxial(+), $n_\alpha = 1.7$–1.702, $n_\beta = 1.72$–1.722, $n_\gamma = 1.747$–1.752, $\delta = 0.047$–0.0500, $2V_z = 80$–$84°$
Localities in Macedonia:	Sivec

Diaspore occurs in the form of platy, tabular or acicular crystals. It may also be found in massive, granular, stalactitic, foliated and scaly habits. It is a transparent to translucent mineral with vitreous luster and white streak. Diaspore occurs in altered igneous rocks, clay deposites and in marbles. It is associated with magnetite, dolomite, corundum, bauxites and other aluminium-rich clay minerals. Diaspore is in fact alpha-phase of AlO(OH), whereas it gama-phase is known as boehmite. Diaspore is often constituent of the bauxite – a mineralogical term generically referring to mixture of aluminium hydroxide minerals of uncertain identity.

The diaspore occurrences in Macedonia are related to the dolomite marbles at Sivec and Pletvar. It is metamorphic and occurs associated with calcite, dolomite, corundum, fluorite, chlorite, pyrite etc.

Mineral identification based on the IR spectral data given in: Frost et al., 1999; Kloprogge et al., 2002; Nicodom, 1998; Ruan et al., 2002; Stegmann, 1973.

Diaspore from Sivec



FT IR spectrum of diaspore

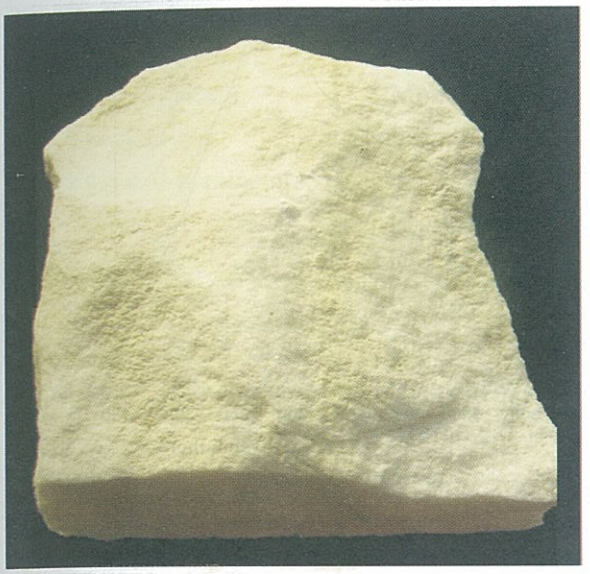
6. Dolomite, $CaMg(CO_3)_2$

Name origin:	Named after the French mineralogist and geologist D. de Dolomieu (1750–1801)
Crystal system:	Hexagonal (rhombohedral)
Space group:	$R\bar{3}$
Unit cell parameters:	$a = 4.842$, $c = 15.95$ Å , $Z = 3$
Color:	White, gray, colorless, yellow, brown
Hardness:	3.5–4
Density:	2.84 (exp.); 2.84 (calc.)
Cleavage:	{101} (rhombohedral) perfect.
Optical characteristics:	Uniaxial(–), $n_\omega = 1.679$–1.690 , $n_\varepsilon = 1.500$–1.510, $\delta = 0.179$–0.182
Localities in Macedonia:	Sivec, Alšar, Ržanovo

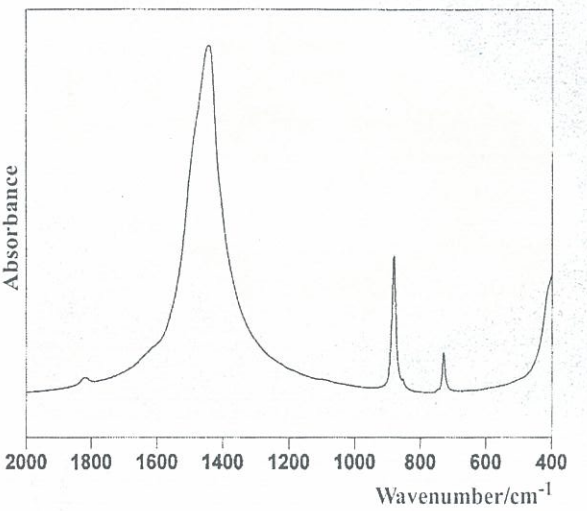
Dolomite is very common mineral. The crystals of dolomite are rhombohedral and rarely prismatic. Dolomite also forms massive and granular habits. It occurs commonly in hydrothermal vein deposits, in serpentinite veins and in altered magnesium limestones. It is associated with calcite, magnesite, siderite, etc. Dolomite is one of the constituents of the marbles. It has vitreous luster and white streak. Although most Mg is currently extracted from sea water, dolomite is potential ore for metallic Mg and MgO production. It is used for glass making, wastewater treatment, portland cement manufacture, asphalt concretion, feed additive for cattle and poultry, monuments creation, etc.

Dolomite occurrences in the Republic of Macedonia are abundant. They comprise portions of some geological formations. They have been found as massive forms occurring, in some cases, as dolomite sands. Their genesis differs depending on the geological processes in which they developed. Thus, in Ržanovo they are a product of alteration of ultrabasic rocks, in the Alšar area they are products of hydrothermal alterations, in the vicinity of Sivec they are products of metamorphic transformations, whereas in some localities in Western Macedonia they are of sedimentary origin.

Mineral identification based on the IR spectral data given in: Jovanovski et al., 2002; Nicodom, 1998; White, 1974.



Dolomite from Sivec



FT IR spectrum of dolomite

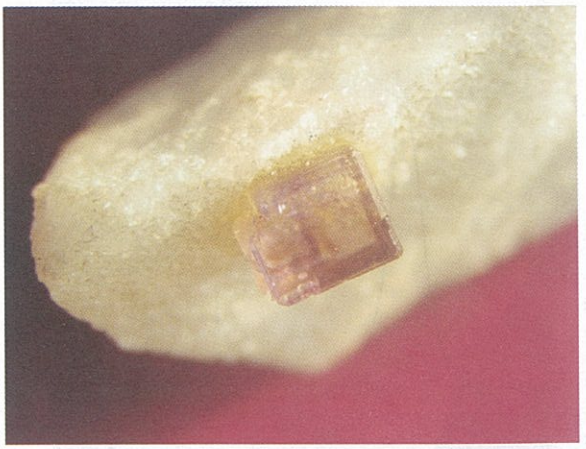
7. Fluorite, CaF_2

Name origin:	After its composition containing fluorine. Latin *fluere*, meaning *to flow*
Crystal system:	Cubic (isometric)
Space group:	*Fm*3*m*
Unit cell parameters:	$a = 5.463$ Å, $Z = 4$
Color:	White, yellow, green, red, blue
Hardness:	4
Density:	3.13 (exp.); 3.18 (calc.)
Cleavage:	{111} perfect
Optical characteristics:	Isotropic, $n = 1.433$
Localities in Macedonia:	Sivec

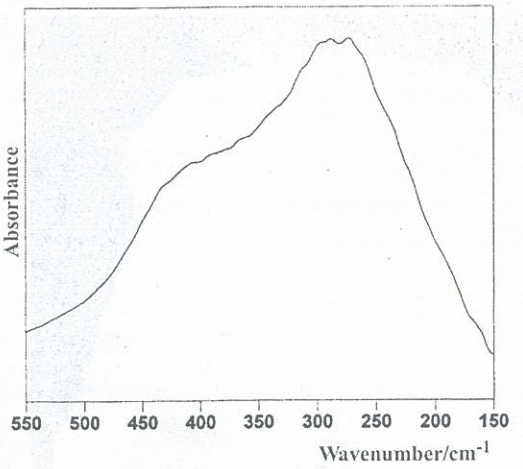
Fluorite most commonly forms cubes, and rarely octahedra and rhombododecahedra. The crystals are very often twinned. This mineral may also occur in granular, compact and massive habits. It is one of the minerals with largest varieties of colours, ranging from white to black (purple, green, yellow, pink, red, blue, brown, colourless). Fluorite is transparent to translucent with vitreous luster and white streak. It occurs in hydrothermal mineral veins and around hot springs. Fluorite is associated with quartz, calcite, dolomite, barite, galena, sphalerite, gypsum, anhydrite, tourmaline and other minerals. This mineral is the main source of fluorine used in chemical industry. Fluorite is also used in steelmaking and other metallurgical processes, in special optics and as an additive in toothpastes.

Fluorite in the Republic of Macedonia has been identified in the dolomite marbles of Sivec. It occurs as very nice crystals of pinkish-bluish colour. It is of note that they are individual crystals. Fluorite is not a common mineral.

Mineral identification based on the IR spectral data given in: Eigeles & Marchenk, 1970; Fitzgerald et al., 2001; Karasik et al., 1998; Mielczarski et al., 1983; Namjoshi et al., 1975.



Fluorite from Sivec



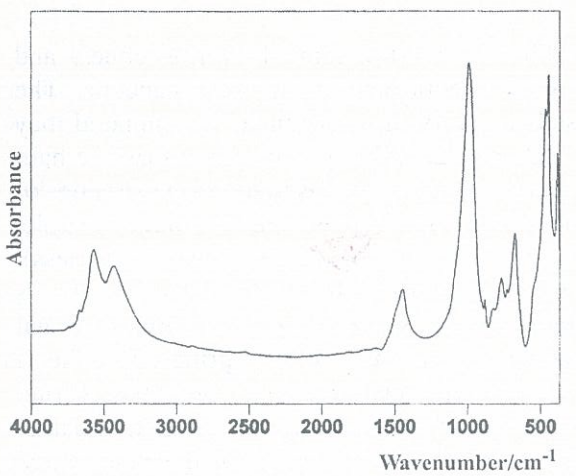
FT IR spectrum of fluorite

8. Clintonite or **margarite, $Ca(Mg,Al)_3(Al_3Si)O_{10}(OH)_2$** [known as kosmatite (Erdmannsdorffer, 1925)]

Name origin:	Named for De Witt Clinton (1769–1828), American statesman
Crystal system:	Monoclinic
Space group:	*C*2/*m*
Unit cell parameters:	$a = 5.306$, $b = 9.135$, $c = 10.272$, $\beta = 100.01°$, $Z = 2$
Color:	Colorless, green, yellow, red, reddish brown
Hardness:	4–5
Density:	3–3.1
Cleavage:	{001} perfect
Optical characteristics:	Biaxial(–), $n_\alpha = 1.643–1.648$, $n_\beta = 1.655–1.662$, $n_\gamma = 1.655–1.663$, $\delta = 0.0120–0.0150$, $2V_z = 0–40°$
Localities in Macedonia:	Sivec

Mineral identification based on the IR spectral data given in Franz et al., 1977.

Kosmatite from Sivec



FT IR spectrum of kosmatite

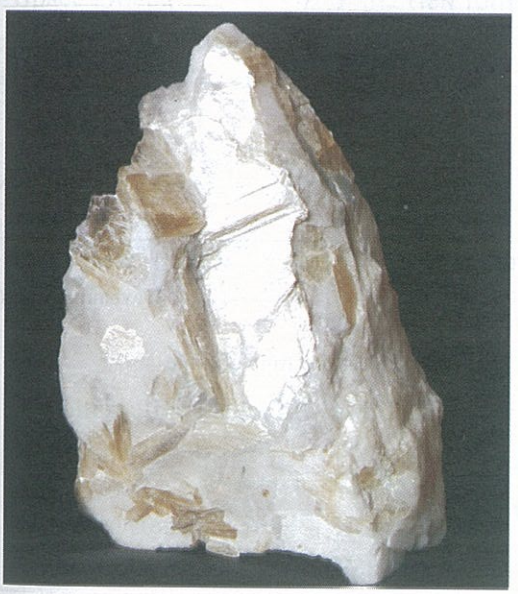
9. Phlogopite, $KMg_3(Si_3Al)O_{10}(F,OH)_2$

Name origin:	From the Greek *flogopos* (*φλογοπος*), meaning *to resemble fire*
Crystal system:	Monoclinic
Space group:	*C2/m*
Unit cell parameters:	$a = 5.31$, $b = 9.20$, $c = 10.20$ Å, $\beta = 99.82°$, $Z = 2$
Color:	Brown, gray, green, reddish brown, yellow, colorless, white
Hardness:	2–2.5
Density:	2.8 (exp.); 2.83 (calc.)
Cleavage:	{001} perfect.
Optical characteristics:	Biaxial(–), $n_\alpha = 1.53–1.573$, $n_\beta = 1.557–1.617$, $n_\gamma = 1.558–1.618$, $\delta = 0.0280–0.0450$, $2V_x = 0–12°$
Localities in Macedonia:	Sivec

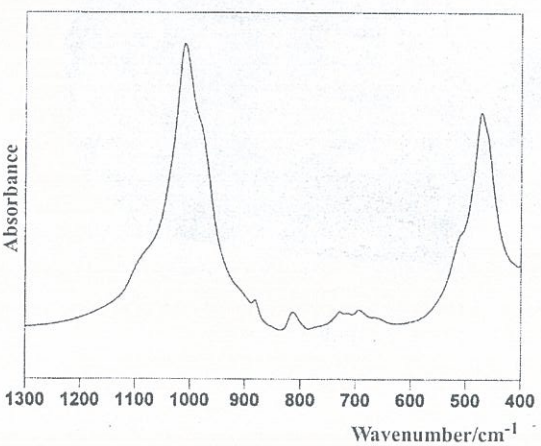
Phlogopite crystallizes in the form of prismatic and pseudo-hexagonal crystals. It also occurs in the form of platy and scaly aggregates or massive. Crystals are often twinned. It is transparent to translucent mineral with vitreous to pearly luster and white streak. Phlogopite occurs in metamorphic and some ultrabasic igneous rocks. It is commonly associated with dolomite, diopside and chlorite.

Phlogopite occurrences in the Republic of Macedonia are related to the dolomite marbles of Sivec in the vicinity of Prilep. It does not occur frequently. It occurs predominantly in the cracks of dolomite marbles or in association with calcite.

Mineral identification based on the IR spectral data given in: Farmer & Russell, 1964; Mellini et al., 2002; Salisbury et al., 1992; Stubican & Roy, 1961; Vedder, 1964.



Phlogopite from Sivec



FT IR spectrum of phlogopite

10. Rutile, TiO_2

Name origin:	From the Latin *rutilus*, meaning *reddish*
Crystal system:	Tetragonal
Space group:	*P4/mnm*
Unit cell parameters:	$a = 4.594$, $c = 2.958$ Å, $Z = 2$
Color:	Blood red, bluish, brownish yellow, brown red, violet

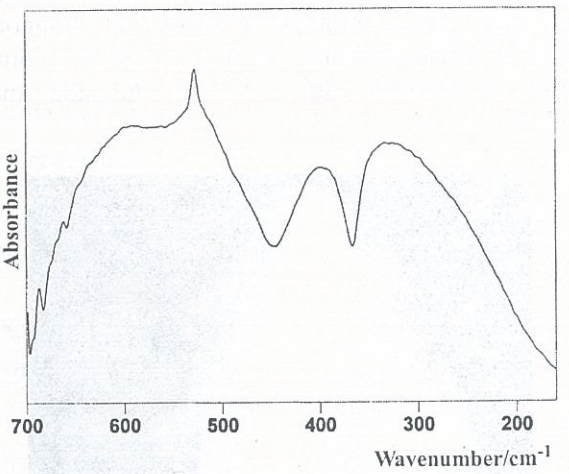
Hardness:	6–6.5
Density:	4.25 (exp.); 4.25 (calc.)
Cleavage:	{110} distinct
Optical characteristics:	Uniaxial(+), n_ω = 2.605–2.621 , n_ε = 2.899–2.908, δ = 0.2870–0.2940
Localities in Macedonia:	Veselčani, Sivec, Oreovo, Patiška Reka

Rutile is one of the three polymorphs of TiO_2. Another two forms are anatase and brookite. The crystals of rutile are prismatic. Sometimes acicular crystals occur as well. Knee-shaped or geniculate twins are very often. Rutile may also be massive in habit. It is an accessory mineral in igneous rocks but also in gneisses, schists, granular limestone and dolomite. The crystals of rutile are transparent to opaque with submetallic to adamantine luster and grayish black streak. It is associated with quartz, kyanite, albite, calcite, fluorite and other minerals. As most common titanium mineral rutile is used as a Ti ore.

Beautiful rutile crystals in the Republic of Macedonia have been determined in Mt Selečka (the Veselčani and Oreovo sites) as well as Sivec locality and Patiška Reka. Rutile crystals occur within quartz pegmatite veins crosscutting metamorphic schists. In some cases they are very large, predominantly twinned, individual crystals.

Mineral identification based on the IR spectral data given in: Luxon & Summitt, 1969; McDevitt & Baun, 1964; Ocana & Serna, 1991, Nicodom, 1998.

Rutile from Sivec



FT IR spectrum of rutile

Non-collected minerals

1. Muscovite, $KAl_2(Si_3Al)O_{10}(OH,F)_2$

Name origin:	From the Russian province of *Muscovy* and the Latin word *vitrum,* meaning *glass* (*Muscovy glass*)
Crystal system:	Monoclinic
Space group:	*C2/m*
Unit cell parameters:	a = 5.19, b = 9.03, c = 20.05 Å, β = 95.5°, Z = 4
Color:	White, silver white, brownish white, gray, greenish white, red, violet
Hardness:	2.5–4 (depending on direction)
Density:	2.82 (exp.); 2.83 (calc.)

Cleavage: {001} perfect.
Optical characteristics: Biaxial(–), n_α = 1.552–1.574, n_β = 1.582–1.61, n_γ = 1.586–1.616, δ = 0.0340–0.0420, $2V_x$ = 30–47°.
Localities in Macedonia: Kokre, Pelagon, Belutče, Čanište, Vitolište, Dunje, Sivec

2. Pyrite, FeS_2

Name origin: From the Greek word *puros* (πυρός), meaning *fire*, in allusion to the sparking produced when iron is struck by a lump of pyrite,
Crystal system: Cubic (isomteric)
Space group: *Pa*3
Unit cell parameters: a = 5.417 Å, Z = 4
Color: Pale yellow
Hardness: 6.5
Density: 5.01 (exp.); 5.01 (calc.)
Cleavage: {100} poor.
Optical characteristics: Opaque.
Localities in Macedonia: Zletovo, Toranica, Damjan, Bučim, Sasa, Sivec

3. Quartz, SiO_2

Name origin: From the German *Quartz*, of uncertain origin
Crystal system: Hexagonal (rhombohedral or trigonal)
Space group: $P\,3_12$ (left form), $P\,3_22$ (right form)
Unit cell parameters: a = 4.9133, c = 5.4053 Å, Z = 3
Color: Colorless, white, yellow, brown, violet, pink, green, black
Hardness: 7
Density: 2.62 (exp.); 2.65 (calc.)
Cleavage: {010} indinstinct
Optical characteristics: Uniaxial(+), n_ω = 1.543–1.545, n_ε = 1.552–1.554, δ = 0.0090
Localities in Macedonia: Belutče, Budinarci, Alinci, Čanište, Saždevo, Mariovo, Sasa, Zletovo, Bučim, Košino, Sivec

4. Tourmaline (schörl), $NaFe^{3+}{}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$

Name origin: Name tourmaline comes from the Singalic word *turmali,* meaning *nice color*, whereas *schörl* is an old German word of unknown origin
Crystal system: Hexagonal (rhombohedral)
Space group: *R*3*m*
Unit cell parameters: a = 15.99, c = 7.195 Å, Z = 3
Color: Black, brownish black, greenish black, bluish black
Hardness: 7.5
Density: 3.15 (exp.); 3.29 (calc.)
Cleavage: {101} indistinct
Optical characteristics: Uniaxial(–), n_ω = 1.66–1.672, n_ε = 1.633–1.64, δ = 0.0270–0.0320.
Localities in Macedonia: Dunje, Bonče, Sasa, Sivec

5. Zoisite, $Ca_2Al_3[(SiO_4)(Si_2O_7)]O(OH)$

Name origin:	After the Austrian natural scientist *S. Zois* (1747 – 1819)
Crystal system:	Orthorhombic
Space group:	*Pnmc*
Unit cell parameters:	a = 16.24, b = 5.58, c = 10.1 Å, Z = 4.
Color:	Gray, apple green, brown, blue, red, yellow
Luster:	Vitreous – pearly
Streak:	White
Habit:	Prismatic crystals, columnar, striated.
Hardness:	6.5
Density:	3.3 (exp.); 3.30 (calc.)
Cleavage:	[010] perfect
Optical characteristics:	Biaxial(+), n_α = 1.696–1.7, n_β = 1.696–1.702, n_γ = 1.702–1.718, δ = 0.0060–0.0180, $2V_x = 0 - 70^\circ$
Localities in Macedonia:	Sivec

CONCLUSION

Investigations carried out on the minerals of the sugary-white marbles of the Sivec site indicated that infrared spectroscopy can very well determine the collected minerals: dolomite, calcite, fluorite, rutile, phlogopite, corundum, diaspore, almandine, kosmatite (clintonite and margarite), clinochlore. Investigated minerals possess clear IR spectra that are very similar to the spectra presented in the materials published.

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Резиме

МИНЕРАЛИ ОД МАКЕДОНИЈА

XV. МИНЕРАЛИ ОД СИВЕЦ

Блажо Боев[1], Глигор Јовановски[2], Петре Макрески[2], Vladimir Bermanec[3]

[1]*Катедра за петрологија, минералогија и геохемија, Рударско-геолошки факултет, Универзитет „Св. Кирил и Методиј", Гоце Делчев 89, МК-2000 Штип, Република Македонија*

[2]*Институт за хемија, Природно-математички факултет, Универзитет „Св. Кирил и Методиј", п. фах 162, МК-1001 Скопје, Република Македонија*

[3]*Institute of Mineralogy and Petrology, Department of Geology, Faculty of Science, University of Zagreb, Horvatovac bb, HR-10000 Zagreb, Croatia*

bboev@rgf.ukim.edu.mk

Клучни зборови: Сивец; Република Македонија; минерална асоцијација; инфрацрвена спектроскопија

Во овој труд се презентирани истражувањата направени на минералите од локалитетот Сивец. Овој локалитет, што се наоѓа близу градот Прилеп, претставува редок случај на постоење на шекерно-белиот доломитен мермер. Освен појавата на доломитниот мермер, за минерализацијата во Сивец се карак-

ристични и други минерали како што се: калцит, флуорит, рутил, флогопит, корунд, дијаспор, алмандин, косматит (клинтонит или маргарит), клинохлор, мусковит, кварц, пирит, турмалин, цоизит. Направен е обид да се идентификуваат десетте собрани минерали од овој локалитет со користење на инфрацрвената спектроскопија. Идентификацијата на минералите е базирана на споредбата на добиените спектри со соодветните досегашни литературни податоци. Прикажани се и фотографии во боја од изучуваните примероци.