Глигор Јовановски

Gligor JOVANOVSKI,
SS. Cyril and Methodius University, Faculty of Science, Institute of Chemistry
(Skopje, Republic of Macedonia)
Blažo BOEV,
Goce Delčev University, Faculty of Natural and Technical Sciences,
(Štip, Republic of Macedonia)
Petre MAKRESKI,
SS. Cyril and Methodius University, Faculty of Science, Institute of Chemistry
(Skopje, Republic of Macedonia)

MINERALS FROM THE REPUBLIC OF MACEDONIA WITH AN INTRODUCTION TO MINERALOGY

Preface

The Republic of Macedonia (also termed R. Macedonia in this book) lies in the Alpine–Balkan–Carpathian–Dinaride collision belt. The country is rich in minerals, especially a large number of oxide, sulfide, carbonate, sulfate, silicate and other types of ore deposits. For instance, there is a unique ore deposit at Alšar (internationally recognised as Allchar), near Kavadarci, where 44 mineral species have been identified, five of them (thallium minerals) unique and present only at this locality in the world. An additional two unique zinc oxide minerals have also been found in the vicinity of Nežilovo. Accordingly, the total number of endemic minerals identified in the Republic of Macedonia is seven.

Despite these rich ore deposits in a relatively small geographical area, the total number of minerals present in the Republic of Macedonia had not been fully established until recently. There were some incomplete mineral collections, but no complete record of the minerals from the R. Macedonia. To prepare the monograph of *Minerals from the Republic of Macedonia*, the systematic process of the collection, separation, identification and spectroscopic and structural characterisation of local minerals was undertaken. The results are presented in this atlas.

The first section presents the terms mineral and mineralogy, mineral formation processes, crystalline state and chemical compositions of minerals, crystallography, chemistry of minerals, important physical properties of minerals, methods for mineral study and identification and mineral classification.

The second section concerns the geological characteristics of the R. Macedonia and the mineralogical deposits from which the minerals were collected as well as the results of the detailed study of 79 various mineral species. A brief description of the main characteristics of 66 mineral deposits is presented. The origin of all studied individual minerals is also described.

The study results were obtained by using vibrational spectroscopy (infrared and Raman) and X-ray powder diffraction. Native elements and various types of oxide, hydroxide, halide, sulfide, arsenide, antimonide, carbonate, sulfate, molibdate, phosphate, arsenate

and silicate minerals originating from the R. Macedonia were detected, identified and characterised. Identification was based on comparing the results of our study with the corresponding literature data for the analogous mineral species originating from other localities in the world. In general, the comparison of the data was often challenging for a number of reasons including: the temperatures at which experiments were performed; the instruments' resolutions; the studied vibrational spectral region and/or the 2θ region of the registered X-ray powder diffraction patterns; the specimen quantity used; sample preparation, particle size and shape; and the locality where the specimen was collected from.

The structural and spectroscopic studies were performed by X-ray powder diffraction and Fourier transform infrared and Raman vibrational spectroscopy, respectively. Furthermore, the chemical composition and presence and content of trace elements in the minerals were determined by using an electron microprobe analyser and by the application of atomic absorption spectrometry and inductively coupled plasma–atomic emission spectrometry (see section 2.4). The results are published in 89 scientific papers (mostly in international journals).

Each individual mineral is subdivided into two sections. In the first, the description of the well-known physical and chemical properties of the corresponding mineral types (including chemical formula, name origin, colour, hardness, density, cleavage, optical characteristics, crystal forms, occurrence, etc.) is presented in the small table and in the first paragraph of the text. In the second paragraph of the text, the characteristics of the corresponding minerals collected from various localities across the R. Macedonia are provided (e.g. occurrence, association, colour, dimension). The infrared and Raman spectra and *d*-values and the unit cell parameters derived from the X-ray powder diffraction data for all studied individual minerals are presented as well.

The number of currently identified and described minerals from the R. Macedonia that were unavailable and not studied systematically by us was about 50. A short description of the physical and chemical properties and a complete list of the corresponding references concerning these minerals are also presented.

The monograph is illustrated with about 350 colour photographs including for all studied minerals. The samples for the illustrations were chosen from the mineral collection at the Institute of Chemistry, Faculty of Natural Sciences and Mathematics, SS. Cyril and Methodius University in Skopje (where about 250 mineral samples are available, including all studied 79 mineral species) and from the mineral collections at the Macedonian Museum of Natural History, Skopje.

1. INTRODUCTION TO MINERALOGY

1.1. Mineral and Mineralogy

Compared with the Earth's 4600 million years of history, the whole of human history is no longer than the blink of an eye. In other words, our current calendar of about 2000 years is only 0.00004% of the whole Earth's life [1]. During this long and complicated period of its life, the Earth has evolved from a totally molten magma to a planet with the rigid surface that consists of solid rock materials composed of one or more minerals.

The term mineral originates from the Latin word *mineralis*, which means that the corresponding material needs to be mined [2]. The term mineral is used in a variety of ways. For instance, all materials extracted from the earth (e.g. oil, coal, iron ore, lead ore, copper ore), from an economic point of view, are minerals. In common usage, anything, except animals and vegetables, could in some way be considered mineral. By contrast, all nutritionally important elements and chemical compounds are considered minerals. From a geoscientific point of view, there are various definitions for mineral in the literature. One of the more acceptable definitions is that a mineral is a *naturally occurring crystalline solid with definite, but not necessarily fixed, chemical composition* [3].

Substances found in the natural environment and formed without the benefit of human intervention are called *minerals*, whereas crystalline solids with the same chemical and physical properties as their mineral counterparts synthesised in the laboratory are known as *synthetic analogues of minerals*. Solids lacking long-range atomic order are considered *amorphous* and, in general, are not minerals.

Although more than 4700 minerals have been identified and named (now appro-aching 5000), less than 100 of these are common and make up all of the Earth's rocks [1, 3–6]. In addition to the various criteria that should be fulfilled before a new mineral name is approved, crystal structure and chemical composition must be determined and a mineral sample should be preserved in a museum, collection of a research institute or other appropriate repository. In general, minerals are named after their chemical compositions, characteristic physical properties, localities where they were found or individuals. Their names are approved by the *Commission on New Minerals and New Mineral Names* of the *International Mineralogical Association.*

The branch of the science that studies mineral forms and structures, their chemical compositions and physical properties and their formation processes and presence in the Earth's core (lithosphere) is called **mineralogy**. Although the beginning of mineralogy extends back to the prehistoric period, the earliest preserved book dealing with rocks and minerals, entitled *On Stones*, was written by Theophrastus (ca. 387–272 BC) [3]. About 400 years later (ca. 77 AD) an encyclopaedic review of mineralogy was provided. A more modern and detailed description of minerals (such as their hardness and cleavage) was published some 1500 years later (1556) by G. Agricola [3]. A series of books by prominent mineralogists were then published between the 17th to 20th centuries. The results of the modern study of mineralogy are continuously published in distinguished mineralogical journals and reviews. Mineralogy reached its highest progress after the discovery of X-rays, which are now used to determine the crystal structures of minerals [3, 4].

1.4.1. Symmetry Elements and Symmetry Operations

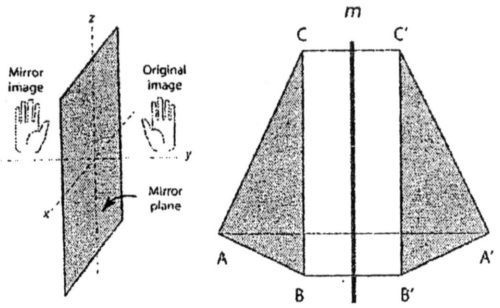
The regular repetitive three-dimensional arrangement of the atoms in the structure of crystals (minerals) is followed by their displaying of symmetry. Therefore, the general concept of crystallography is based on understanding symmetry. In general, two types of symmetry exist: *point symmetry* and *translational symmetry*. Point symmetry refers to the repetition of the motif around the point, whereas translational symmetry concerns the repetition (translation) of the motif through the volume [3, 4, 11, 12].

Point Symmetry

The repeated motifs in crystals (minerals) are three-dimensionally arranged *atoms* forming the crystal structure or the crystal *faces* determining the corresponding crystal form. Three types of possible point symmetry elements and corresponding operations exist: mirror plane/reflection (symbol: *m*); rotation axes/rotation (symbol: N = 1, 2, 3, 4, 6) and the centre of symmetry/inversion (symbol: *i*). Symmetry is recognised either about the centre of the crystal or about the origin of the unit cell.

Mirror Plane / Reflection: m

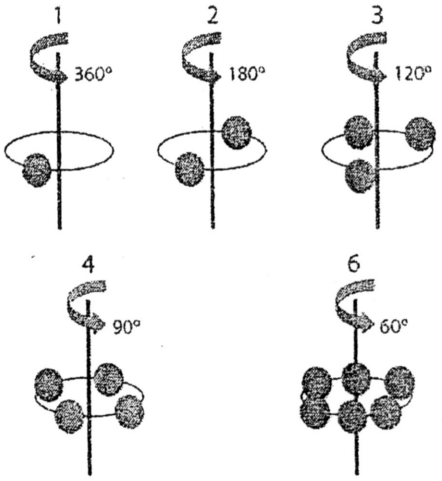
The mirror plane (*m*) operates on the crystal structure or the crystal faces of the mineral. The mirror plane passing through the crystal structure reflects the atoms on one side as the mirror image on the other, whereas the mirror plane passing through the crystal reflects the mineral faces into two equivalent crystal images.



Mirror plane of reflection

***Rotation Axes / Rotation*: N = 1, 2, 3, 4, 6**

Five types of rotation axes and corresponding rotations that repeat the atoms in the structure or the crystal faces of the mineral exist. They are called one-fold, two-fold, three-fold, four-fold and six-fold axes/rotations and involve repetitions of the atoms or mineral faces after rotations of 360°, 180°, 120°, 90° and 60°, respectively. The corresponding notations are 1, 2, 3, 4 and 6.



One-fold, two-fold, three-fold, four-fold and six-fold rotation axes

1.7. Methods for Mineral Study and Identification

The study of physical properties such as colour, lustre, streak, density, hardness, cleavage, refractive index, taste, odour and reaction with acid is the first step in the procedure of identifying unknown minerals. A series of additional experimental techniques should, however, be performed to complete mineral identification and characterisation. The most frequently used and powerful techniques are chemical analysis, X-ray diffraction, vibrational (infrared and Raman) spectroscopy, thermal methods and optical methods. Here, we will briefly present the techniques to identify and characterise the minerals of Macedonia.

1.7.1. Chemical Analysis

The determination of chemical composition is one of the first and most important steps in the process of mineral identification. It can be performed through a variety of analytical methods such as *wet chemical methods* and different *instrumental procedures* including atomic absorption and emission spectrometry, mass spectrometry, neutron activation analysis, X-ray fluorescence spectroscopy and electron probe microanalysis [3, 4, 8].

Electron Probe Microanalysis

Electron probe microanalysis is one of the most frequently used techniques for determining mineral chemical composition [3, 4]. It is based on directing a focused beam of electrons onto the studied sample to produce a characteristic X-ray spectrum of the present elements in the studied sample. A tungsten filament (at very high temperatures and a high voltage) is used to generate free electrons. These electrons are focused into a very fine beam that at a high velocity strikes the sample and dislodges the inner-shell electrons from the atoms of the studied sample. The higher energy (upper-shell) electrons immediately drop into the vacant lover energy (inner-shell) sites, thereby emitting the characteristic X-ray spectrum. The intensity of the emitted X-rays is proportional to the amount of the present element in the mineral. This method measures very small quantities of the constitutional mineral elements (down to the concentrations on the order of 0.1 to 0.01 wt% or approximately 10–11 g).

1.7.2. X-ray Diffraction

The interaction of X-rays with the minerals enables the determination of the detailed arrangement of the atoms or ions in their structures. This can identify the minerals and explain their physical and chemical properties. Namely, the interatomic distances in the crystal structures of minerals are similar to the wavelengths (λ) of the characteristic X-rays (around 0.7 to 2.3 Å). At the appropriate angle of diffraction θ, this makes it possible for the layers of regularly arranged atoms in the crystal to reflect (diffract) the incident X-rays. This type of interaction is explained by the Bragg equation:

$$n\lambda = 2d\sin\theta$$

where n is an integer, λ is wavelength of the X-rays, d is the interplanar distance and θ is the angle between the layer and the direction of the diffracted X-rays (see figure below). The intensities of the diffracted X-rays by various layers (at different θ values) depend on the electron densities of the corresponding layers. Increasing the electron density of the layer

gives rise to a higher intensity of the corresponding reflection. In the later stage, crystal structure analysis is used as a tool to determine the positions of atoms or ions in the structure of the mineral [3, 4, 12, 16].

When many microcrystals with different orientations are present as the targets of X-rays instead of the properly oriented single crystal, the powder X-ray diffraction method is used for mineral identification. The powdered sample of the mineral is mounted onto a special holder that moves relative to the incident X-ray beam and allows the angle θ to vary between zero and 90°. The intensity of the reflected X-rays from the corresponding layers of the randomly oriented crystals is measured by the electronic X-ray detector and registered electronically on a computer or on paper. Each peak of relevant intensity corresponds to the atomic layer (plane) with appropriate *d*-spacing to reflect the X-rays for the particular angle θ. The obtained data by the diffractometer are registered as the intensities of the corresponding peaks at various 2θ values.

Since each mineral has its own crystal structure with its corresponding arrangement of atoms or ions in the planes at specific *d*-spacings, the identification of unknown minerals is based on the comparison of its *d*-spacings and reflection intensities with the corresponding values for the known mineral.

The powder X-ray diffraction data for minerals (and other compounds) are compiled by the International Centre for Diffraction Data and are known as Powder Diffraction File (PDF). The same data are also available on CD-ROM.

1.7.3. Vibrational (Infrared and Raman) Spectroscopy

Vibrational spectroscopy is based on the use of the corresponding type of radiation for the investigation of the vibrational behaviour of the substances (minerals). The absorption of infrared radiation by the substance is called *infrared vibrational spectroscopy*, whereas the phenomenon of the Raman scattering of the incident beam is termed *Raman vibrational spectroscopy* [16–18]. The corresponding vibrations of the molecules (polyatomic groups) allow interaction with incident radiation, raising the molecules from its lowest vibrational energy level (v = 0) to the excited vibrational energy level (v = 1). The energy difference (ΔE) between the two energy levels (states) is $\Delta E = h\nu$, where h is the Planck constant and ν is the vibrational frequency. The energy of the ground vibrational state is called *zero point energy* and is determined by the equation $E_0 = 1/2(h\nu_0)$. The frequency of the interatomic vibration (oscillation) of the diatomic molecule is determined by the equation:

$$\nu = 1/2\pi\,(k/\mu)^{1/2}$$

where k is the force constant of the bond and μ the so-called reduced mass (m_1m_2/m_1+m_2) of the oscillator. The corresponding vibration is termed the *normal vibrational mode*.

In infrared spectroscopy, the infrared radiation interacts with the specimen, which absorbs at the frequencies (wavelengths) corresponding to the energy of the vibrational transmissions. Consequently, a series of various bands with different intensities and frequencies appears.

Visible light (monochromatic laser beam) interacts with the specimen in Raman vibrational

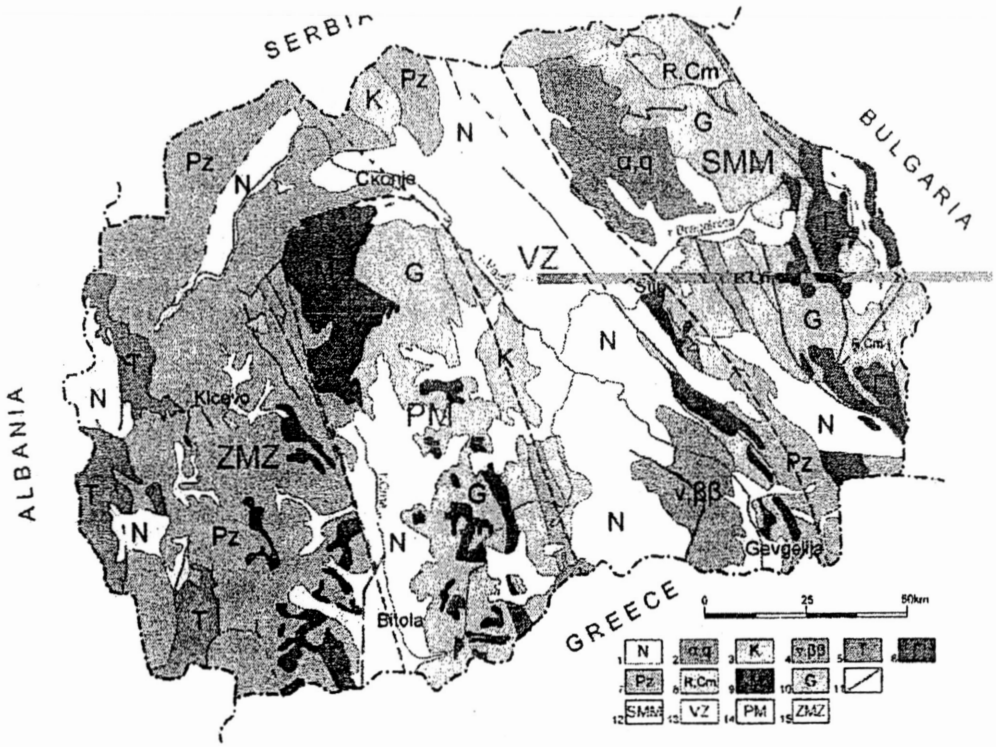
spectroscopy. The great majority of the incident light passes through the specimen, but a small portion scatters from the atoms and causes the corresponding vibrational motions. Thereby, the energy (frequency) of this scattered light that causes vibrational transmissions decreases (*inelastic Raman scattering*), whereas the portion of light that does not change in frequency (energy) is called *elastic (Rayleigh) scattering*. A series of bands appear in the spectrum as result of the inelastic Raman scattering. Their frequencies depend on the corresponding changes in energy for a particular vibrational transmission.

The use of these two complementary techniques (infrared and Raman vibrational spectroscopy) in the process of mineral identification and characterisation is recommended. The advantages of Raman spectroscopy are a broader frequency range (4000–10 cm^{-1}, compared with the ordinary 4000–200 cm^{-1} region in infrared); the possibility of a laser beam focusing on the micro-Raman spectroscopy on a very small area (1 μm^2); and better separation of the narrow Raman bands. The appearance of fluorescence and need for a laser component colour of visible light that corresponds to the specimen colour are, in some ways, disadvantages of Raman spectroscopy.

2. MINERALS FROM THE REPUBLIC OF MACEDONIA

2.1. Geological Characteristics of the Republic of Macedonia

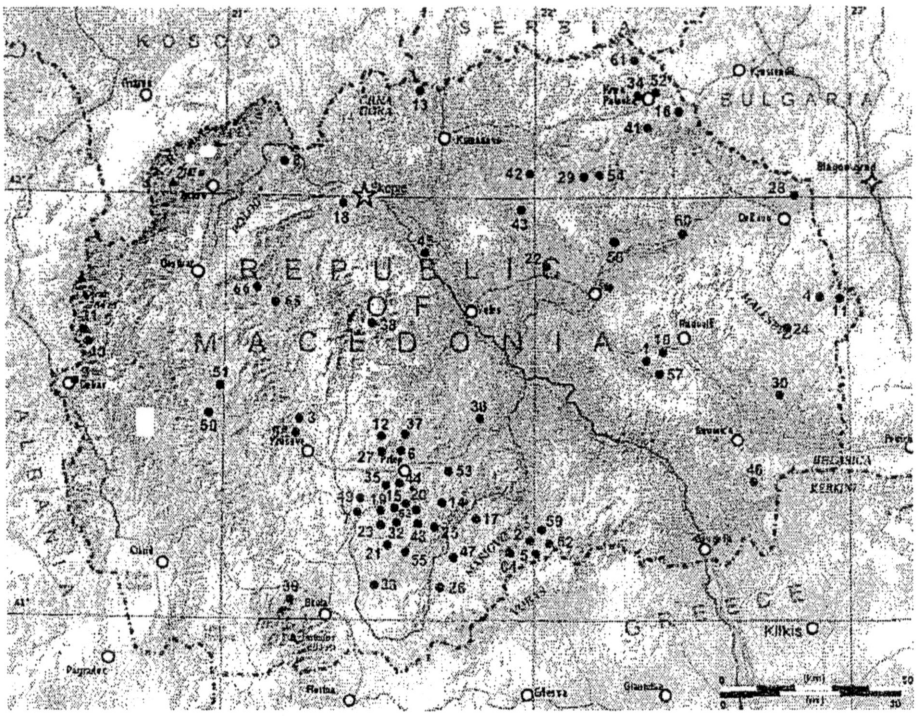
In general, four geotectonic regions (units) are present on the territory of the Republic of Macedonia: West-Macedonian zone (WMZ); Pelagonian massif (PM); Vardar zone (VZ); Serbo-Macedonian massif (SMM) [1].



The geological map of the Republic of Macedonia:
1. Neogene; 2. Volcanics; 3. Cretaceous; 4. Gabbros-diabases; 5. Triassic; 6. Granitoids; 7. Palaeozoic; 8. Riphean-Cambrian; 9. Marbles; 10. Gneisses; 11. Faults; 12. SMM; 13. VZ; 14. PM; 15. WMZ

2.2. Deposits of the collected minerals of the Republic of Macedonia

The mineral localities within the territory of R. Macedonia are given in the map below.



Map of the deposits in the Republic of Macedonia where the minerals were collected from:
(1) Damjan, (2) Ržanovo, (3) Košino, (4) Pehčevo, (5) Alšar, (6) Sivec, (7) Veselčani, (8) Raduša, (9) Debar, (10) Bučim, (11) Bukovik, (12) Pelagon, (13) Lojane, (14) Dunje, (15) Štavica, (16) Sasa, (17) Vrbsko, (18) Vodno, (19) Alinci, (20) Belutče, (21) Bešište, (22) Bogoslovec, (23) Bonče, (24) Budinarci, (25) Veprčani, (26) Vitolište, (27) Drenovci, (28) Zvegor, (29) Zletovo, (30) Ilovica, (31) Kobilino Pole, (32) Kokre, (33) Krastov Kamen, (34) Ginovci, (35) Lagovo, (36) Mrzen, (37) Nebregovo, (38) Nežilovo, (39) Nižepole, (40) Nistrovo, (41) Petrova Reka, (42) Plavica, (43) Plešenci, (44) Prilepec, (45) Pčinja, (46) Rabrovo, (47) Ramna Niva, (48) Selečka Planina, (49) Staro Bonče, (50) Strelci, (51) Tajmište, (52) Toranica, (53) Trojaci, (54) Crni Vrv, (55) Čanište, (56) Češinovo, (57) Šopur, (58) Saždevo, (59) Mrežičko, (60) Osojnica, (61) Krstov Dol, (62) Vasov Grad, (63) Čumovo, (64) Kozjak, (65) Brest, (66) Peklište

2.2.1. Alinci

The Alinci (Crni Kamen) deposit is situated 11 km south-west of Prilep close to the Alinci village. It covers an area of 4 km^2 and is built up of alkali syenites, gneisses, muscovite schists and marbles. Alkali syenite is present as a 2 km magmatic body confined by amphiboles from the east and west. Coarse-grained and fine-grained syenites are made up of microcline, arfvedsonite, albite and minor titanite, augite, zircon and apatite. Gneiss and quartz microcline veins have been found within the syenite body. Amphibolite schists form the southern portion of the syenite massif [1]. A specific trait of the deposit is its rare mineral paragenesis, which includes uranium minerals [2].

There are frequent nests of several centimetres in size filled with needle-like arfvedsonite crystals [3]. Arfvedsonite is a mineral of the amphibole group occurring as acicular shapes of green or dark blue. It appears as an inclusion in other mineral forms, namely within the

nentioned arfvedsonite nests; idiomorphic crystals of other minerals also often appear in he feldspar veins [2]. Albite is also common, appearing as platy white to totally transparent :rystals. The largest crystals reach 10 cm in size. Twinned individual grains (polysynthetically winned) or Carlsbad's twins are common. Arfvedsonite crystals are frequent inclusions in ılbite.

Of note are the well-developed quartz crystals, the large titanite crystals (reaching 2 cm n size) and the crystals of microcline, monazite, senaite (formerly determined as davidite) ınd macedonite. Titanite crystals from the Alinci locality grow within arfvedsonite nests ınd develop their complete shape as single or, often, twinned crystals [2]. It has been estimated that the largest titanite twins from this locality have reached 25 cm in length and could have weighed several kilograms. Unfortunately, they have been damaged during nine explosions, but some crystals up to 8 cm in size have survived. The Alinci deposit is also well known after the first discovered and described lead titanate named macedonite (from Macedonia). Microcline crystals at this deposit (which sometimes measure 20 cm in length) are often intergrown with the crystals of arfvedsonite. The presence of arfvedsonite inclusions can completely darken the microcline crystals from the Alinci deposit.

2.3. Identified Minerals from the Republic of Macedonia

2.3.7. Silicates

Silicates Studied by the Authors
Kyanite, Al_2SiO_5

Name Origin:	From the Greek *kyanos* (κυανοσ) meaning *blue*
Colour:	Blue, white, grey, green, black
Hardness:	5–7
Density:	3.61 (exp.); 3.67 (calc.)
Cleavage:	{100} perfect, {010} imperfect
Optical Characteristics:	Biaxial(–), n_α = 1.712–1.718, n_β = 1.72–1.725, n_γ = 1.727–1.734, δ = 0.0150–0.0160, $2V_x$ = 78–84°

Localities in the R. Macedonia: Čumovo, Lagovo, Pelagon, Prilepec, Staro Bonče, Štavica.

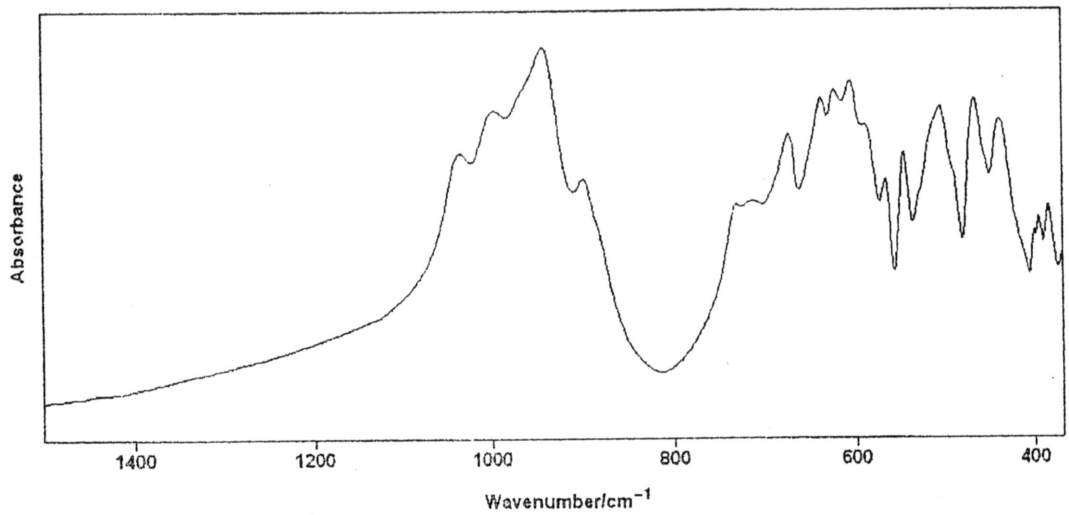
Kyanite forms elongated prismatic to tabular and bladed crystals. It also occurs in fibrous aggregates and granular or massive habits. Lamellar twinning is common. Kyanite is a transparent to translucent mineral with a vitreous to dull lustre and white streak. It occurs in metamorphic rocks (schists and gneisses) and less frequently in magmatic rocks (pegmatites and granites). Kyanite is associated with its polymorphic analogues sillimanite and andalusite and with almandine, staurolite, talc and corundum.

Kyanite occurrences in the PM can be seen in several places. It occurs associated with almandine, staurolite, quartz and biotite. The best kyanite crystals can be found in the Staro Bonče and Štavica localities. They appear on the surfaces of the exposed rocks in the form of beautiful elongated prismatic and tabular blue to grey crystals. The largest crystals are about 20 cm long and occur rarely only in the massive white quartz veins. Small amounts of kyanite have been found in a quartz body at the Štavica site. This body is regarded as a rarity.

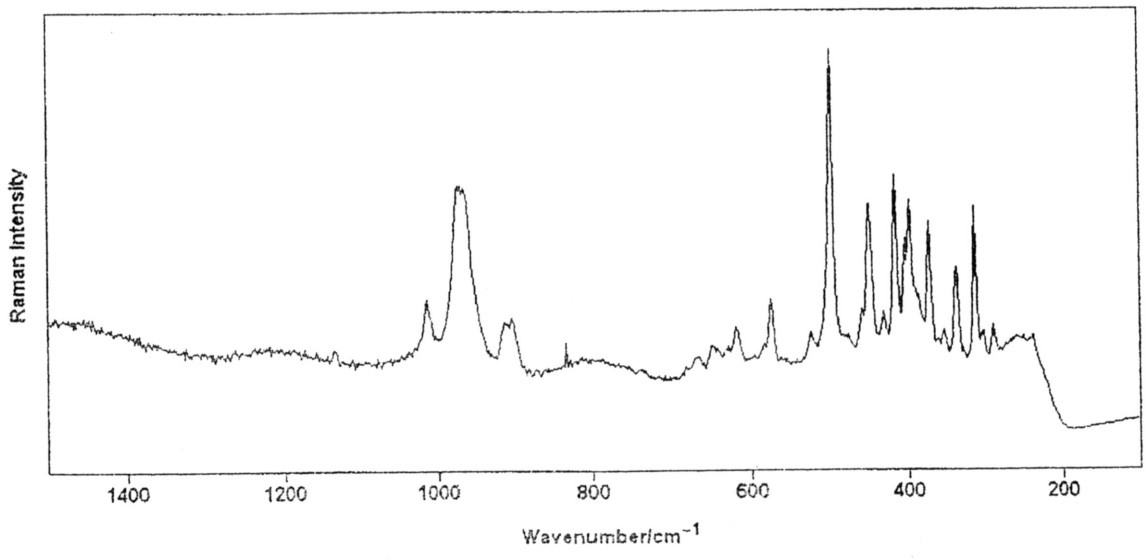
X-ray microprobe analysis

Element oxides	Content / %			
	Point 1	Point 2	Point 3	Theoretical
Na_2O	<0.01	<0.01	<0.01	
MgO	<0.01	<0.01	<0.01	
Al_2O_3	65.04	63.74	63.27	62.92
SiO_2	34.94	35.99	35.86	37.08
K_2O	<0.01	<0.01	<0.01	
CaO	<0.01	<0.01	0.22	
TiO_2	<0.01	<0.01	<0.01	
MnO	<0.01	<0.01	<0.01	
Fe_2O_3	<0.01	0.18	0.28	
Total	99.98	99.91	99.63	100

IR spectrum



Raman spectrum



X-ray powder diagram

h	k	l	d_{obs}	d_{cal}	d_{diff}
-1	0	0	6.7171	6.7155	0.0016
1	-1	0	5.9095	5.9064	0.0031
-1	-1	0	4.4359	4.4341	0.0018
0	1	1	4.3158	4.3087	0.0071
0	2	0	3.7697	3.7699	-0.0002
-2	1	0	3.4478	3.4485	-0.0007
-2	0	0	3.3576	3.3578	-0.0002
1	1	1	3.1924	3.1946	-0.0022
0	2	1	3.0261	3.0265	-0.0004
-2	2	0	2.9533	2.9532	0.0001
-2	-1	0	2.7900	2.7898	0.0002
2	-1	1	2.7018	2.7018	0.0000
-1	1	2	2.6078	2.6082	-0.0004
0	-3	0	2.5133	2.5133	0.0000
2	-3	0	2.3543	2.3543	0.0000
0	3	1	2.2380	2.2380	0.0000
3	-1	1	2.0098	2.0096	0.0002
1	-4	0	1.9640	1.9641	-0.0001
-3	3	1	1.9360	1.9361	-0.0001
1	2	2	1.8846	1.8847	-0.0001

Unit Cell Par.^{obs}	Unit Cell Par.*
a = 7.1242 Å	a = 7.1240 Å
b = 7.8504 Å	b = 7.8517 Å
c = 5.5503 Å	c = 5.5762 Å
α = 89.78 °	α = 89.86 °
β = 101.05 °	β = 101.13 °
γ = 106.05 °	γ = 106.032 °
V = 292.384 Å^3	V = 293.70 Å^3
	Z = 4
	Triclinic (P-1)

*H. Yang, R. T. Downs, L. W. Finger, R. M. Hazen, C. T. Prewitt, Compressibility and Crystal Structure of Kyanite, Al_2SiO_5, at High Pressure, *American Mineralogist*, **82**, 467–474 (1997).

2.4. Published Papers by the Members of the Research Group Regarding the Studies of Minerals from the Republic of Macedonia

1. T. Stafilov, T. Todorovski, Determination of Gold in Arsenic-antimony Ore by Flameless Atomic Absorption Spectrometry, *Atomic Spectroscopy*, **8**, 12–14 (1987).

2. T. Stafilov, T. Todorovski, B. Grozdanova, L. Spandževa, Determination of Thallium in Ore from Allchar by Atomic Absorption Spectrometry, *Nuclear Instruments and Methods*

in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, **271**, 321–323 (1988).

3. T Stafilov, T. Todorovski, Determination of Gold in Arsenic-Antimony Ore by X-ray Fluorescence Spectrometry, *Technical Faculty in Bor, Proceedings*, **24**, 199–207 (1988).

4. T. Stafilov, V. Jordanovska, S. Aleksovska, Determination of Lead in Antimonite by Electrothermal Atomic Absorption Spectrometry, *Vestnik Slovenskega Kemijskega Drustva*, **37**, 141–148 (1990).

5. T. Stafilov, T. Todorovski, Determination of Molibdenum un Arsenic-antimony Ore by Flameless Atomic Absorption Spectrometry, *Atomic Spectroscopy*, **11**, 202–204 (1990).

6. T. Stafilov, V. Jordanovska, S. Aleksovska, Determination of Lead in Arsenic Minerals from Alshar by Atomic Absorption Spectrometry, *Bulletin of the Chemists and Technologists of Macedonia*, **9**, 159–166 (1990).

7. T. Stafilov, Application of Electrothermal Atomic Absorption Spectrometry in the Analysis of Samples Present in the Process of Iron and Steel Production, *Metalurgija*, **30**, 75–80 (1991) (in Serbian).

8. M. Trajkovska, B. Šoptrajanov, G. Jovanovski, T. Stafilov, Vibrational Spectra of Some Sulfide Minerals from Alšar, *Journal of Molecular Structure*, **267**, 191–196 (1992).

9. T. Stafilov, B. Ristova, M. Ristov, Determination of Bismuth in Copper Concentrate by Atomic Absorption Spectrometry, *Geologica Macedonica*, **6**, 98–103 (1992).

10. B. Šoptrajanov, M. Trajkovska, I. Gržetić, G. Jovanovski, T. Stafilov, Infrared Spectra of $M^{I}_{3}M^{III}S_{3}$ Type Synthetic Minerals (M^{I} = Tl or Ag, M^{III} = As or Sb), *Neues Jahrbuch für Mineralogie-Abhandlungen*, **166**, 83–89 (1993).

11. T. Stafilov, A. Lazaru, E. Pernicka, Determination of Thallium in Sulfide Minerals by Zeeman Electrothermal Atomic Absorption Spectrometry, *Acta Chimica Slovenica*, **40**, 37–46 (1993).

12. T. Balić Žunić, T. Stafilov, D. Tibljaš, Distribution of Thallium and the Ore Genesis at Crven Dol Locality in Alshar, *Geologica Macedonica*, **7**, 45–52 (1993).

13. M. Trajkovska, B, Šoptrajanov, T. Stafilov, G. Jovanovski, Determination of Lorandite and Realgar in Mineral Mixtures by Infrared Spectroscopy, *Geologica Macedonica*, **7**, 55–59 (1993).

14. A. Lazaru, T. Stafilov, Determination of Fe, Mn, Cu, Cr and Ni in Sulfide Minerals from Alšar by Atomic Absorption Spectrometry, *Geologica Macedonica*, **7**, 73–80 (1993).

15. T. Stafilov, S. Aleksovska, V. Jordanovska, Determination of Lead in Some Sulfidic Minerals from Alshar, *Geologica Macedonica*, **7**, 81 (1993).

16. B. Šoptrajanov, M. Trajkovska, G. Jovanovski, T. Stafilov, Infrared Spectra of Lorandite and Some Other Minerals From Alšar, *Neues Jahrbuch für Mineralogie-Abhandlungen*, **167**, 329–337 (1994).

17. T. Stafilov, S. Aleksovska, V. Jordanovska, Determination of Lead in Lorandite and Marcasite from Alcchar by Electrothermal Atomic Absorption Spectrometry, *Neues Jahrbuch für Mineralogie-Abhandlungen*, **167**, 401–408 (1994).

18. B. Petrov, D. Andonova, T. Stafilov, T. Novakovski, Possibility of Concentration Thallium Mineral Lorandite from the Allchar Deposit, Crven Dol Region, *Neues Jahrbuch für Mineralogie-Abhandlungen*, **167**, 413–420 (1994).

19. B. Ristova, T. Stafilov, M. Ristov, Determination of Nickel and Cobalt in Copper Ore

and Concentrate by Atomic Absorption Spectrometry, *Geologica Macedonica*, **8**, 67–69 (1994).

20. A. Lazaru, T. Stafilov, Determination of Cobalt and Zinc in Some Minerals from Alshar Mine by Atomic Absorption Spectrometry, *XXVIth October Meeting of the Miners and Metallurgists, Donji Milanovac, Proceedings,* 427–431 (1994).

21. T. Stafilov, A. Lazaru, E. Pernicka, Determination of Silver in Sulfide Minerals by Electrothermal Atomic Absorption Spectrometry, *Atomic Spectroscopy*, **16**, 158–161 (1995).

22. T. Stafilov, A. Lazaru, Determination of Lead in Dolomite by Zeeman Electrothermal Atomic Absorption Spectrometry, *Geologica Macedonica*, **9**, 83–86 (1996).

23. B. Šoptrajanov, M. Trajkovska, T. Stafilov, G. Jovanovski, I. Gržetić, Infrared Spectra of Three $M^{I}M^{III}S_2$ Type Synthetic Minerals (M^{I} = Ag or Tl, M^{III} = Sb or As), *Spectroscopy Letters*, **30**, 79–87 (1997).

24. A. Lazaru, T. Stafilov, Determination of Copper in Dolomite by Electrothermal Atomic Absorption Spectrometry, *Analytical Laboratory*, **6**, 101–103 (1997).

25. A. Lazaru, T. Stafilov, Determination of Copper in Sulfide Minerals by Zeeman Electrothermal Atomic Absorption Spectrometry, *Fresenius' Journal of Analytical Chemistry*, **360**, 726–728 (1998).

26. D. Mihajlović, T. Stafilov, Determination of Thallium in Geological Samples by X-ray Fluorescence Spectrometry, *X-ray Spectrometry*, **27**, 397–400 (1998).

27. A. Lazaru, R. Ilić, J. Skvarč, E. S. Krištof, T. Stafilov, Neutron Induced Autoradiography of Some Minerals from Alchar Mines, *Radiation Measurements*, **31**, 677–682 (1999).

28. G. Jovanovski, V. Stefov, B. Jovanovski, B. Šoptrajanov, B. Boev, Minerals from Macedonia. III. Determination of Calcite and Aragonite in Mineral Mixtures Using FT IR Spectroscopy, *Geologica Macedonica,* **13**, 69–74 (1999).

29. D. Zendelovska, T. Stafilov, B. Boev, Determination of Zn, Mn and Fe in Some Minerals by Flame Atomic Absorption Spectrometry, *Geologica Macedonica,* **13**, 91–96 (1999).

30. G. Jovanovski, V. Stefov, B. Jovanovski, B. Šoptrajanov, B. Kaitner, Minerals from Macedonia. I. Analytical Application of Powder X-ray Diffraction Patterns of Calcite and Aragonite, *16th Congress of Chemists and Technologists of Macedonia, Skopje, Proceedings*, 43–46 (1999).

31. V. Stefov, S. Dimitrovska, G. Jovanovski, B. Šoptrajanov, Minerals from Macedonia. II. Vibrational Spectra of Some Sulfate Minerals, *16th Congress of Chemists and Technologists of Macedonia, Skopje, Proceedings*, 47–50 (1999) (in Macedonian).

32. D. Zendelovska, T. Stafilov, Determination of Zn, Mn and Fe in Minerals by Flame Atomic Absorption Spectrometry, *16th Congress of Chemists and Technologists of Macedonia, Skopje, Proceedings*, 423–426 (1999).

33. T. Stafilov, Determination of Trace Elements in Minerals by Electrothermal Atomic Absorption Spectrometry, *Spectrochimica Acta Part B-Atomic Spectroscopy*, **55**, 893–906 (2000).

34. T. Stafilov, D. Zendelovska, Determination of Cobalt, Copper, Lead and Nickel in Gypsum by Zeeman Electrothermal Atomic Absorption Spectrometry, *Acta Chimica Slovenica*, **47**, 381–388 (2000).

35. A. Lazaru, T. Stafilov, Determination of Co, Ni and Pb in Arsenic Minerals by Zeeman

Electrothermal Atomic Absorption Spectrometry, *Bulletin of the Chemists and Technologists of Macedonia*, **19**, 21–26 (2000).

36. B. Boev, V. Stefov, Serpentine Minerals in Some Geochemical Samples from the Blace Border Crossing (Republic of Macedonia), *Geologica Macedonica*, **14**, 55–60 (2000).

37. V. Stefov, G. Jovanovski, B. Šoptrajanov, B. Minčeva-Šukarova, S. Dimitrovska, B. Boev, Minerals from Macedonia. V. Characterization of Gypsum, Barite and Their Synthetic Analogues by FTIR and Raman Spectroscopy, *Geologica Macedonica*, **14**, 61–66 (2000).

38. D. Zendelovska, T. Stafilov, B. Boev, Determination of Co, Ni, Cr and Cu in Galena and Sphalerite by Zeeman Electrothermal Atomic Absorption Spectrometry, *Geologica Macedonica*, **14**, 67–73 (2000).

39. D. Zendelovska, G. Pavlovska, K. Čundeva, T. Stafilov, Electrothermal Atomic Absorption Spectrometric Determination of Cobalt, Copper, Lead and Nickel Traces in Aragonite Following Flotation and Extraction Separation, *Talanta*, **54**, 139–146 (2001).

40. D. Zendelovska, T. Stafilov, Extraction Separation and Electrothermal Atomic Absorption Spectrometric Determination of Thallium in Some Sulfide Minerals, *Analytical Sciences*, **17**, 425–428 (2001).

41. B. Boev, Y. Yanev, Tertiary Magmatism within the Republic of Macedonia, *Acta Volcanologica*, **13**, 57–71 (2001).

42. T. Stafilov, D. Mihajlović, Determination of Thallium in Geological Samples by Electrothermal Atomic Absorption Spectrometry, *Journal of the Institute of Science and Technology of the Balikesir University*, **3**, 104–124 (2001).

43. D. M. Arabadžiev, V. Stefov, T. Stafilov, B, Boev, Physicochemical Investigation of Limestones from Different Localities in the Republic of Macedonia, *Geologica Macedonica*, **15–16**, 35–41 (2001–2002).

44. P. Makreski, G. Jovanovski, V. Stefov, B. Minčeva-Šukarova, B. Kaitner, B. Boev, Minerals from Macedonia. VI. Separation and Identification of Some Sulfide Minerals, *Geologica Macedonica*, **15**, 43–50 (2001–2002).

45. B. Boev, V. Bermanec, T. Serafimovski, S. Lepitkova, S. Mikulčić, M. Šoufek, G. Jovanovski, T. Stafilov, M. Najdoski, Allchar Mineral Assemblage, *Geologica Macedonica*, **15–16** (Supplement), 1–23 (2001–2002).

46. B. Boev, V. Stefov, Fibrous Silicates in the Environment, *3rd International Symposium for Mining and Environmental Protection, Belgrade, Proceedings*, 407–410 (2001).

47. B. Boev, S. Lepitkova, The Earth's Heat, *1st Conference on Geothermal Energy in the Republic of Macedonia, Strumica, Proceedings*, 49–55 (2001).

48. V. Bermanec, L. A. Palinkas, S. Strmic, R. Gault, B. Boev, V. Zebec, Mineralogy of Pegmatite with Giant Epidote Crystals, near Čaniste, Macedonia, *Joint 6th Biennial SGA-SEG Meeting – Mineral Deposits at the Beginning of the 21st century, Krakow, Proceedings*, 939–942 (2001).

49. G. Jovanovski, V. Stefov, B. Šoptrajanov, B. Boev, Minerals from Macedonia. IV. Discrimination Between Some Carbonate Minerals by FTIR Spectroscopy, *Neues Jahrbuch für Mineralogie-Abhandlungen*, **177**, 241–253 (2002).

50. T. Stafilov, D. Zendelovska, Determination of Trace Elements in Iron Minerals by Atomic Absorption Spectrometry, *Turkish Journal of Chemistry*, **26**, 271–280 (2002).

51. A. Lazaru, R. Jaćimović, R. Ilić, D. Mihajlović, T. Stafilov, Determination of Major and

Trace Elements in Some Minerals by k_0-NAA, *Journal of Radioanalytical and Nuclear Chemistry*, **253**, 427–434 (2002).

52. T. Stafilov, D. Zendelovska, G. Pavlovska, K. Čundeva, Flotation Separation used as a Method for Elimination of Matrix Interferences on Trace Elements in Dolomite and Gypsum for their Atomic Absorption Spectrometric Determination, *Spectrochimica Acta Part B-Atomic Spectroscopy*, **57**, 907–917 (2002).

53. B. Boev, S. Lepitkova, G. Petrov, Granitoid Formations in the Republic of Macedonia, *Geologica Carpatica*, **53**, CD version (2002).

54. B. Boev, S. Lepitkova, The Age of Ophiolite Rocks in the Territory of the Republic of Macedonia, *Geologica Carpatica*, **53**, CD version (2002).

55. K. Čundeva, G. Pavlovska, T. Stafilov and D. Zendelovska, Applicability of Iron(III) Hexamethylenedithiocarbamate as Colloid Collector for Flotation Preconcentration and Separation of Some Trace Elements in Aragonite before their AAS Determination, *Journal of the Institute of Science and Technology of the Balikesir University*, **4**, 9–12 (2002).

56. B. Ristova, T. Stafilov, D. Mihajlović, Using of Chemical Modifiers in ETAAS Determination of Selenium in Copper Concentrate, *Journal of the Institute of Science and Technology of the Balikesir University*, **4**, 23–25 (2002).

57. K. Čundeva, T. Stafilov, D. Zendelovska, G. Pavlovska, Application of Coprecipitate Flotation As a Method for Selective Separation of Heavy Metal Trace Impurities in Dolomite and Gypsum and their ETAAS Determination, *Bulletin of the Chemists and Technologists of Macedonia*, **21**, 43–52 (2002).

58. G. Jovanovski, B. Minčeva-Šukarova, P. Makreski, B. Šoptrajanov, W. P. Griffith, R. L. Willis, Minerals from Macedonia. VII. Raman Spectra of Sulfide Minerals from the Allchar Deposit (Stibnite, Realgar, Orpiment and Lorandite), *XVIIIth International Conference of Raman Spectroscopy, Budapest, Proceedings*, 931–932 (2002).

59. G. Jovanovski, B. Minčeva-Šukarova, P. Makreski, V. Stefov, W. P. Griffith, R. L. Willis, Minerals from Macedonia. VIII. Raman Spectra of Some Sulfide Minerals from the Localities in East Macedonia, *XVIIIth International Conference of Raman Spectroscopy, Budapest, Proceedings*, 933–934 (2002).

60. T. Stafilov, Extraction and ETAAS Determination of Trace Elements in Minerals, *3rd Aegean Analytical Chemistry Days, Polihnotos, Proceedings*, 23–25 (2002).

61. P. Makreski, V. Zajkova Paneva, G. Jovanovski. T. Stafilov, D. Zendelovska, AAS and AES-ICP Determination of Trace Elements in Some Iron Minerals, *3rd Aegean Analytical Chemistry Days, Polihnitos, Proceedings*, 440–443 (2002).

62. K. Čundeva, T. Stafilov, D. Zendelovska, G. Pavlovska, Flotation Preconcentration and Determination of Trace Elements in Dolomite by Atomic Absorption Spectrometry, *3rd Aegean Analytical Chemistry Days, Polihnotos, Proceedings*, 515–518 (2002).

63. B. Minčeva-Šukarova, G. Jovanovski, P. Makreski, B. Šoptrajanov, W. Griffith, R. Willis, I. Gržetić, Vibrational Spectra of $M^{I}M^{III}S_2$ Type Synthetic Minerals (M^{I} = Tl or Ag and M^{III} = As or Sb), *Journal of Molecular Structure*, **651–653**, 181–189 (2003).

64. G. Pavlovska, K. Čundeva, T. Stafilov, D. Zendelovska, Flotation Method for Selective Separation of Silver, Cadmium, Chromium, Manganese, Thallium and Zinc from Aragonite before Atomic Absorption Spectrometric Determination, *Separation Science and Technology*, **38**, 1117–1124 (2003).

65. Y. Yanev, B. Boev, G. Doglioni, F. Innocenti, P. Maneti, S. Lepitkova, Neogene Ultrapotassic-potassic Volcanic Association in the Vardar Zone (Macedonia), *Comptes Rendus de l'Academie Bulgare des Sciences*, **56**, 53–58 (2003).

66. M. Pavicevic, G. Amthauer, B. Boev, Die Bestimmung der Erosionsrate im Allchargebiet (Mazedonia) mit Hilfe Langlebiger Kosmogener Radionuklide, *Mitteilungen der Österreichischen Mineralogischen Gesellschaft*, **148**, 249–250 (2003).

67. P. Makreski, G. Jovanovski, Minerals from Macedonia. IX. Discrimination between Some Orthorhombic Carbonates by FTIR Spectroscopy, *Bulletin of the Chemists and Technologists of Macedonia*, **22**, 25–32 (2003).

68. G. Jovanovski, B. Boev, P. Makreski, M. Najdoski, G. Mladenovski, Minerals from Macedonia. XI. Silicate Varieties and their Localities – Identification by FT IR Spectroscopy, *Bulletin of the Chemists and Technologists of Macedonia*, **22**, 111–141 (2003).

69. N. Angelov, T. Stafilov, Determination of Trace Elements in Arsenic Minerals by Atomic Absorption Spectrometry with Previous Matrix Modification, *Geologica Macedonica*, **17**, 73–82 (2003).

70. V. Zajkova, T. Stafilov, B. Boev, Flotation Separation of Cd, Co, Cr, Cu, Ni and Tl from Calcium Minerals and their Determination by Inductively Coupled Plasma-Atomic Emission Spectrometry, *Geologica Macedonica*, **17**, 87–93 (2003).

71. P. Makreski, G. Jovanovski, B. Minčeva-Šukarova, B. Šoptrajanov, A. Green, B. Engelen, I. Gržetić, Vibrational Spectra of $M^{I}_{3}M^{III}S_{3}$ Type Synthetic Minerals (M^{I} = Tl or Ag and M^{III} = As or Sb), *Vibrational Spectroscopy*, **35**, 59–65 (2004).

72. P. Makreski, G. Jovanovski, B. Kaitner, T. Stafilov, B. Boev, D. Cibrev, Minerals from Macedonia. X. Separation and Identification of Some Oxide Minerals by FT IR Spectroscopy, AAS, EAS-ICP and Powder XRD, *Neues Jahrbuch für Mineralogie-Abhandlungen*, **180**, 215–243 (2004).

73. M. Pavicevic, E. M. Wild, W. Kutchera, B. Boev, T. Prohaska, M. Berger, I. Stefan, AMS Measurments of ^{26}Al in Quartz to Assess the Cosmic Ray Background for the Geochemical Solar Neutrino Experiment LOREX, *Nuclear Instruments & Methods In Physics Research Section B: Beam Interactions With Materials And Atoms*, **223–224**, 660–667 (2004).

74. M. Pavićević, G. Amthauer, A. Bienok, B. Boev, F. Brandstätter, V. Cvetkovic, R. Jelenković, D. Prelević, T. Prohaska, Die Bestimmung Dererosionsrate im Allchar Gebiet (Mazedonia) mit Hilfe Langlebiger Kosmogener Radionuklide im Quartz, *Berichte der Deutshen Mineralogischen Beihefte zum European Journal of Mineralogy*, **16**, 104–105 (2004).

75. P. Makreski, G. Jovanovski, T. Stafilov, B. Boev, Minerals from Macedonia. XII. The Dependance of Quartz and Opal Color on Trace Element Composition – AAS, FT IR and Micro-Raman Spectroscopy Study, *Bulletin of the Chemists and Technologists of Macedonia*, **23**, 171–184 (2004).

76. B. Boev, Y. Yanev, Tertiary Pluton Pantelej in the Vardar Zone, Republic of Macedonia, *Geologica Macedonica*, **18**, 31–39 (2004).

77. B. Boev, S. Lepitkova, Tertiary Intrusive Rocks in the Central Part of Vardar Zone, *5th International Symposium on Eastern Mediterranean Geology, Thessaloniki, Proceedings*, 3, 1095–1097 (2004).

78. P. Makreski, G. Jovanovski, S. Stojančeska, Minerals from Macedonia. XIII. Vibrational Spectra of Some Commonly Appearing Nesosilicate Minerals, *Journal of Molelucar Structure*, **744–747**, 79–92 (2005).

79. P. Makreski, G. Jovanovski, S. Dimitrovska, Minerals from Macedonia. XIV. Identification of Some Sulfate Minerals by Vibrational (Infrared and Raman) Spectroscopy, *Vibrational Spectroscopy*, **39**, 229–239 (2005).

80. T. Stafilov, N. Angelov, R. Jaćimović, V. Stibilj, Determination of Trace Elements in Arsenic and Antimony Minerals by Atomic Absorption Spectrometry and k_0-Instrumental Neutron Activation Analysis after As and Sb Removal, *Microchimica Acta*, **149**, 229–237 (2005).

81. V. Zajkova Paneva, K. Čundeva, T. Stafilov, Inductively Coupled Plasma-Atomic Emission Spectrometry as a Method for Determination of Trace Metals in Alkalineearth Matrices Following Flotation Separation, *Spectrochimica Acta Part B-Atomic Spectroscopy*, **60**, 403–407 (2005).

82. M. Teseska, T. Stafilov, P. Makreski, G. Jovanovski, Determination of Trace Elements in Some Copper Minerals by Atomic Absorption Spectrometry, *Ovidius University, Annals of Chemistry*, **16**, 43–46 (2005).

83. R. Jaćimović, P. Makreski, V. Stibilj, T. Stafilov, G. Jovanovski, Characterization of Some Iron Minerals from Republic of Macedonia Using Instrumental Neutron Activation Analysis, *Geologica Macedonica*, **19**, 33–38 (2005).

84. B. Boev, G. Jovanovski, P. Makreski, V. Bermanec, Minerals from Macedonia. XV. Sivec Mineral Assemblage, *Geologica Macedonica*, **19**, 39–56 (2005).

85. G. Jovanovski, P. Makreski, B. Šoptrajanov, B. Kaitner, B. Boev, Minerals from Macedonia. Complementary Use of Vibrational Spectroscopy and Powder X-ray Diffraction for Identification and Detection Purposes, *Contributions, Section of Mathematical and Technical Sciences, Macedonian Academy of Sciences and Arts*, **26**, 7–84 (2005).

86. B. Boev, S. Lepitkova, The Alshar polymetallic deposit and its impact on the water of Lake Tikves, *3rd International Workshop on the UNESCO – IGCP Project: Anthropogenic Effects on the Human Environment in Tertiary Basins in the Mediterranean, Štip, Proceedings*, 70–77 (2005).

87. P. Makreski, G. Jovanovski, A. Gajović, Minerals from Macedonia. XVII. Vibrational Spectra of Common Apearing Amphibole Minerals, *Vibrational Spectroscopy*, **40**, 98–109 (2006).

88. P. Makreski, G. Jovanovski, A. Gajović, T. Biljan, D. Angelkovski, R. Jaćimović, Minerals from Macedonia. XVI. Vibrational Spectra of Some Common Appearing Pyroxene and Pyroxenoids, *Journal of Molecular Structure*, **788**, 102–114 (2006).

89. M. K. Pavićević, V. Cvetković, G. Amthauer, A. Bieniok, B. Boev, F. Brandstätter, M. Götzinger, R. Jelenković, D. Prelević, T. Prohaska, Quartz from Allchar as Monitor for Cosmogenic ^{26}Al: Geochemical and Petrogenetic Constraints, *Mineralogy and Petrology*, **88**, 527–550 (2006).

90. M. Taseska, T. Stafilov, P. Makreski, R. Jaćimović, V. Stibilj, G. Jovanovski, Liquid-liquid Extraction and Determination of Trace Elements in Iron Minerals by Atomic Absorption Spectrometry, *Geologica Macedonica*, **20**, 33–38 (2006).

91. P. Naumov, P. Makreski, G. Jovanovski, Direct Atomicscale Observation of Linkage

Isomerization of As_4S_4 Clusters During the Photoinduced Transition of Realgar to Pararealgar, *Inorganic Chemistry*, **46**, 10624–10631 (2007).

92. P. Makreski, G. Jovanovski, B. Kaitner, A. Gajović, T. Biljan, Minerals from Macedonia. XVIII. Vibrational Spectra of Some Sorosilicates, *Vibrational Spectroscopy*, **44**, 162–170 (2007).

93. V. Šontevska, G. Jovanovski, P. Makreski, Minerals from Macedonia. XIX. Vibrational Spectroscopy as Identificational Tool for Some Sheet Silicate Minerals, *Journal of Molecular Structure*, **834–836**, 318–327 (2007).

94. V. Zajkova Paneva, K. Čundeva, T. Stafilov, Flotation Separation of Trace Elements From Alkalineearth Matrices by Co(III) Hexamethylenedithiocarbamate Before ICP-AES Determination, *Geostandards and Geoanalytical Research*, **31**, 51–60 (2007).

95. R. Jaćimović, M. Taseska, V. Stibilj, P. Makreski, T. Stafilov, G. Jovanovski, Element Composition of Some Copper Minerals from the Republic of Macedonia, *Geologica Macedonica*, **21**, 87–91 (2007).

96. P. Makreski, G. Jovanovski, Minerals from Macedonia. XXII. Laser-induced Fluorescence Bands in the FT-Raman Spectrum of Almandine Mineral, *Journal of Raman Spectroscopy*, **39**, 1210–1213 (2008).

97. V. Šontevska, G. Jovanovski, P. Makreski, A. Raškovska, B. Šoptrajanov, Minerals from Macedonia. XXI. Vibrational Spectroscopy as Identification Tool for Some Phyllosilicate Minerals, *Acta Chimica Slovenica*, **55**, 757–766 (2008).

98. P. Makreski, R. Jaćimović, V. Stibilj, T. Stafilov, G. Jovanovski, Determination of Trace Elements in Iron Minerals by Instrumental and Radiochemical Neutron Activation Analysis, *Radiochimica Acta*, **96**, 855–861 (2008).

99. Y. Yanev, B. Boev, C. Doglioni, F. Innocenti, P. Manetti, Z. Pecskay, S. Tonarini, M. D'Orazio, Late Miocene to Pleistocene Potassic Volcanism in the Republic of Macedonia, *Mineralogy and Petrology*, **94**, 45–60 (2008)

100. M. Taseska, P. Makreski, V. Stibilj, R. Jaćimović, T. Stafilov, G. Jovanovski, Determination of Trace Elements in Chalcopyrite ($CuFeS_2$) by Neutron Activation Analysis After Matrix Elements Removal, *Macedonian Journal of Chemistry and Chemical Engineering*, **27**, 141–147 (2008).

101. G. Jovanovski, B. Boev, P. Makreski, Minerals from Macedonia, *Macedonian Mining and Geology*, **8**, 14–17 (2008) (in Macedonian).

102. P. Makreski, G. Jovanovski, Minerals from Macedonia. XXIII. Spectroscopic and Structural Characterization of Schorl and Beryl Cyclosilicates, *Spectrochimica Acta Part A-Molecular Spectroscopy*, **73**, 460–467 (2009).

103. G. Jovanovski, P. Makreski, B. Kaitner, B. Boev, Silicate Minerals from Macedonia. Complementary Use of Vibrational Spectroscopy and X-ray Powder Diffraction for Identification and Detection Purposes, *Croatica Chemica Acta*, **82**, 363–386 (2009).

104. B. Boev, G. Jovanovski, P. Makreski, Minerals from Macedonia. XX. Geological Setting, Lithological Rock Types and Identification of the Minerals from Ržanovo Fe–Ni Deposit, *Turkish Journal of Earth Sciences*, **18**, 631–652 (2009)

105. P. Makreski, G. Jovanovski, B. Kaitner, Minerals from Macedonia. XXIV. Spectra-structure Characterization of Tectosilicates, *Journal of Molecular Structure*, **924–926**, 413–419 (2009).

106. G. Jovanovski, P. Makreski, B. Kaitner, B. Šoptrajanov, Minerals from Macedonia. X-ray Powder Diffraction *vs.* Vibrational Spectroscopy in Mineral Identification, *Contributions, Section of Mathematical and Technical Sciences, Macedonian Academy of Sciences and Arts*, **30**, 7–34 (2009).

107. M. Tasevska, R. Jaćimović, V. Stibilj, T. Stafilov, P. Makreski, G. Jovanovski, Is Copper Removal by Electrolysis from Copper Minerals Appropriate Method for Determination of Trace Elements?, *Nuclear Instruments & Methods In Physics Research Section A: Accelerators Spectrometers Detectors And Associated Equipment*, **622**, 449–452 (2010).

108. P. Naumov, P. Makreski, G. Petruљevski, T. Runиevski, G. Jovanovski, Visualization of a Discrete Solid-State Process with Steady-State X-ray Diffraction: Observation of Hopping of Sulfur Atoms in Single Crystals of Realgar, *Journal of the American Chemical Society*, **132**, 11398–11401 (2010).

109. P. Makreski, T. Runčevski, G. Jovanovski, Minerals from Macedonia. XXVI. Characterization and Spectra-structure Correlations for Grossular and Uvarovite. Raman Study Supported by IR Spectroscopy, *Journal of Raman Spectroscopy*, (in press).

Mineral Index

(bold – studied minerals by authors; non-bold – other minerals)

Actinolite, $Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
Albite, $NaAlSi_3O_8$
Almandine, $Fe_3Al_2(SiO_4)_3$
Amazonite, $KAlSi_3O_8$ (see microcline)
Anatase, TiO_2
Anhydrite, $CaSO_4$
Antigorite, $(Mg,Fe^{2+})_3Si_2O_5(OH)_4$
Apatite, $Ca_5(PO_4)_3(F,Cl,OH)$
Arfvedsonite, $Na_3(Mg,Fe^{2+})_4(Fe^{3+},Al)Si_8O_{22}(OH)_2$
Aragonite, $CaCO_3$
Arsenolite, As_2O_3
Arsenopyrite, FeAsS
Augite, $(Ca,Na)(Mg,Fe,Al,Ti)(Si,Al)_2O_6$
Azurite, $Cu_3(CO_3)_2(OH)_2$
Barite, $BaSO_4$
Bernardite, $Tl(As,Sb)_5S_8$
Beryl, $Be_3Al_2Si_6O_{18}$
Biotite, $K(Mg,Fe^{2+})_3AlSi_3O_{10}(OH,F)_2$
Brochantite, $Cu_4(SO_4)(OH)_6$
Brucite, $Mg(OH)_2$
Bustamite, $(Mn,Ca)_3Si_3O_9$
Calcite, $CaCO_3$
Carpholite, $MnAl_2Si_2O_6(OH)_4$
Cervantite, Sb_2O_4
Chalcanthite, $CuSO_4 \cdot 5H_2O$

Chalcocite, Cu_2S
Chalcopyrite, $CuFeS_2$
Chromite, $FeO{\cdot}Cr_2O_3$
Chrysotile, $Mg_3Si_2O_5(OH)_4$
Cinnabar, HgS
Clinochlore, $(Mg,Fe^{2+})_5Al(Si_3Al)O_{10}(OH)_8$
Clinozoisite, $Ca_2Al_3(SiO_4)(Si_2O_7)O(OH)$
Copper, Cu
Corundum, Al_2O_3
Cymrite, $BaAl_2Si_2O_8{\cdot}H_2O$
Diaspore, AlO(OH)
Dolomite $CaMg(CO_3)_2$
Dorallcharite, $(Tl,K)_2Fe^{3+}{}_6(SO_4)_4(OH)_{12}$
Enstatite, $Mg_2Si_2O_6$
Epidote, $Ca_2Al_2(Al,Fe^{3+})(Si_2O_7)(SiO_4)O(OH)$
Epsomite, $MgSO_4{\cdot}7H_2O$
Fangite, Tl_3AsS_4
Fibroferrite, $FeSO_4(OH){\cdot}5H_2O$
Fluorite, CaF_2
Forsterite, Mg_2SiO_4
Gahnite, $ZnAl_2O_4$
Galena, PbS
Glaucophane-crossite, $Na_2(Mg,Fe^{2+})_3(Al,Fe^{3+})_2Si_8O_{22}(OH)_2$
Goethite, FeO(OH)
Gold, Au
Greigite, $Fe^{2+}Fe^{3+}{}_2S_4$
Grossular, $Ca_3Al_2(SiO_4)_3$
Gypsum, $CaSO_4{\cdot}2H_2O$
Hedenbergite, $CaFe^{2+}Si_2O_6$
Hedyphane, $Ca_2Pb_3(AsO_4)_3Cl$
Hematite, Fe_2O_3
Hemimorphite, $Zn_4Si_2O_7(OH)_2{\cdot}H_2O$
Heulandite, $(Ca_{0.5},Sr_{0.5},Ba_{0.5},Na,K)_9(Al_9Si_{27}O_{72}){\cdot}24H_2O$
Hornblende, $(Na,K)_{0-1}Ca_2(Mg,Fe^{2+},Fe^{3+},Al)_5(Si,Al)_8O_{22}(OH)_2$
Hornesite, $Mg_3(AsO_4)_2{\cdot}8H_2O$
Ilvaite, $CaFe^{2+}{}_2Fe^{3+}Si_2O_8(OH)$
Jankovićite, $Tl_5Sb_9(As,Sb)_4S_{22}$
Jarosite, $KFe^{3+}{}_3(SO_4)_2(OH)_6$
Kutnahorite, $CaMn(CO_3)_2$
Kyanite, Al_2SiO_5
Lorandite, $TlAsS_2$
Macedonite, $PbTiO_3$
Magnesite, $MgCO_3$
Magnetite, $FeO{\cdot}Fe_2O_3$

Magnetoplumbite, $PbO{\cdot}6R_2O_3$ (R = Fe, Mn,…)
Malachite, $Cu_2CO_3(OH)_2$
Marcasite, FeS_2
Margarite, $CaAl_2(Al_2Si_2)O_{10}(OH)_2$
Melanterite, $FeSO_4{\cdot}7H_2O$
Microcline, $KAlSi_3O_8$
Molybdenite, MoS_2
Monazite, $(La,Ce,Nd)PO_4$
Montmorillonite, $(Na,Ca)_{0.3}(Al,Mg)_2Si_4O_{10}(OH)_2{\cdot}n(H_2O)$
Muscovite, $KAl_2(Si_3Al)O_{10}(OH,F)_2$
Nežilovite, $PbZn_2(Mn^{4+},Ti^{4+})_2Fe^{3+}{}_8O_{19}$
Orpiment, As_2S_3
Parapierrotite, $Tl(Sb,As)_5S_8$
Pararealgar, As_4S_4
Pharmacolite, $CaHAsO_4{\cdot}2H_2O$
Phlogopite, $KMg_3(Si_3Al)O_{10}(F,OH)_2$
Picotpaulite, $TlFe_2S_3$
Picropharmacolite, $Ca_4Mg(AsO_3OH)_2(AsO_4)_2{\cdot}11H_2O$
Piemontite, $Ca_2(Mn^{3+},Fe^{3+})Al_2(SiO_4)(Si_2O_7)O(OH)$
Pyrite, FeS_2
Quartz, SiO_2
Raguinite, $TlFeS_2$
Realgar, As_4S_4
Rebulite, $Tl_5Sb_5As_8S_{22}$
Rhodochrosite, $MnCO_3$
Rhodonite, $(Mn^{2+},Fe^{2+},Mg,Ca)SiO_3$
Roméite, $(Ca,Fe^{2+},Mn,Na)_2(Sb,Ti)_2O_6(O,OH,F)$
Rozenite, $FeSO_4{\cdot}4H_2O$
Rosslerite, $MgHAsO_4{\cdot}7H_2O$
Rutile, TiO_2
Sanidine, $(K,Na)(Si,Al)_4O_8$
Schorl, $NaFe^{3+}{}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$ (see tourmaline)
Senaite, $Pb(Ti,Mn,Fe)_{21}O_{38}$
Siderite, $FeCO_3$
Silver, Ag
Simonite, $TlHgAs_3S_6$
Spessartine, $Mn_3Al_2(SiO_4)_3$
Sphalerite, ZnS
Starkeyite, $MgSO_4{\cdot}4H_2O$
Staurolite, $(Fe^{2+},Mg)_2Al_9(Si,Al)_4O_{20}(O,OH)_4$
Stephanite, Ag_5SbS_4
Stibiconite, $Sb_3O_6(OH)$
Stibnite, Sb_2S_3
Stilbite, $NaCa_4Al_8Si_{28}O_{72}{\cdot}30H_2O$

Struvite, $NH_4MgPO_4 \cdot 6H_2O$
Sulfur, S
Talc, $Mg_3Si_4O_{10}(OH)_2$
Tilasite, $CaMg(AsO_4)F$
Titanite, $CaTiSiO_5$
Tourmaline (schorl), $NaFe^{3+}{}_3Al_6(BO_3)_3Si_6O_{18}(OH)_4$
Uvarovite, $Ca_3Cr_2(SiO_4)_3$
Valentinite, Sb_2O_3
Vivianite, $Fe_3(PO_4)_2 \cdot 8H_2O$
Vrbaite, $Tl_4Hg_3Sb_2As_8S_{20}$
Weissbergite, $TlSbS_2$
Wulfenite, $PbMoO_4$
Zincohogbomite-2N6S, $Zn_{14}(Al,Fe^{3+},Ti,Mg)_8Al_{24}O_{62}(OH)_2$
Zircon, $ZrSiO_4$
Zoisite, $Ca_2Al_3(SiO_4)(Si_2O_7)O(OH)$