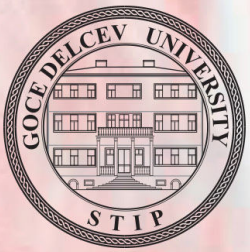

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SEM-EDS INVESTIGATIONS OF THE PEGMATITE VEIN-DUNJE (PELAGONIAIN METAMORPHIC COMPLEX), OCCURRENCE OF TITANITE ON RUTILE BASE

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Abstract
In the pegmatite body of the locality Dunje (Pelagonian metamorphic complex) the association rutile-titanite was examined using the SEM-EDS method and it has been determined that rutile appears as the first generation within the metamorphic evolution of the Pelagon, while titanite appears as the second one as a result of metamorphic-metasomatic processes in the presence of a fluid phase rich in Ca, Fe, P, Si.

Key words: *titanite, rutile, pegmatite*

INTRODUCTION

The Pelagonian metamorphic complex is the largest unit of the belt. It is situated between the Vardar zone and the Dinaride (West Vardar) ophiolite belt on the territories of North Macedonia and Greece (Florina "terrane") [1-6].

The geological structure of the Pelagonian metamorphic complex includes metamorphic and igneous rocks of the pre-Cambrian age [7].

Metamorphic rocks have the largest distribution in the terrain and are represented by gneisses and micas and transitional rocks between them. The rocks have a high crystallinity which is a result of the high degree of metamorphism. Based on their mineral composition, the following varieties of gneisses can be distinguished: muscovite-biotite, muscovite, biotite gneisses (they are made of albite), microcline, quartz, muscovite and biotite as main minerals. Zircon, apatite, and titanite appear as accessory minerals.

Micaschists are less common than gneisses, and are made of quartz and mica, and kyanite, staurolite and garnet appear as porphyroblasts. In addition to gneisses and micaschists, there are migmatites that are made of biotite and amphibole, as well as amphibolites.

Magmatic rocks are represented by different types of granites and gneiss granites as well as leukocratic granites, aplites and pegmatites. The granites are made of the following minerals: quartz, orthoclase, biotite, muscovite, and zircon, apatite, ilmenite, and titanite appear as accessory minerals.

The pegmatite veinlets vary from a few centimeters to a few decimeters in width, and are intruded along heavily foliated Precambrian gneisses, which are sometimes accompanied by amphibolites. General foliation inclination in gneiss and amphibolite as measured in the field is ENE dipping on average at 30°. This coincides with the orientation of the Veprčani monocline [7-9]. Granitic rocks, which also intrude the Precambrian metamorphic suite, outcrop roughly 100 m out of the pegmatite location in NNE direction displaying typical granite (exfoliation) jointing

In the upper parts of the complex there are metamorphic rocks from the group of marbles and cipolines. These are mainly dolomite- calcite marbles.

MATERIAL AND METHODS

Geological characteristics of the pegmatite body near the village of Dunje

On the eastern slopes of Selecka Mountain, in Smilevski Dol, about 3 km SW from the village of Dunje, in the vicinity of a small spring called Sohleov Kladenec, there is a hydrothermal pegmatite vein that appears at the contact between the granites and the gneisses. Within the pegmatite body, there is a specific mineral association which is represented by albite, microcline, amphibole, epidote, titanite, quartz, muscovite, chlorite, stilbite, heulandite, pyrite, apatite, and rutile [10-16]

The gneisses in the contact parts with the granites had a pronounced foliation and are made of epidote-clinozoisite, amphibole (actinolite), quartz, plagioclase, titanite and rare accessory minerals (Figure 1) [17].

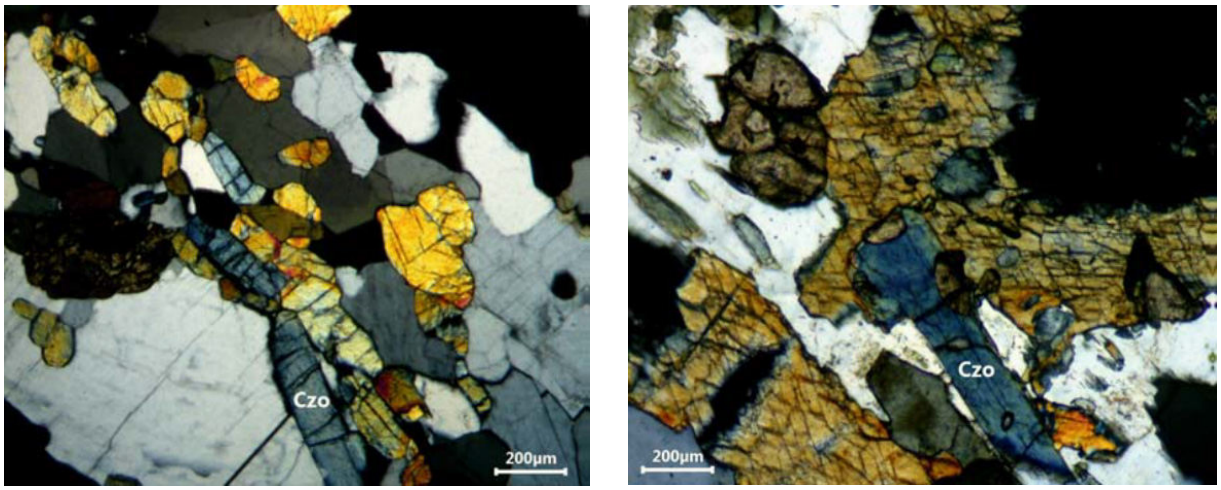


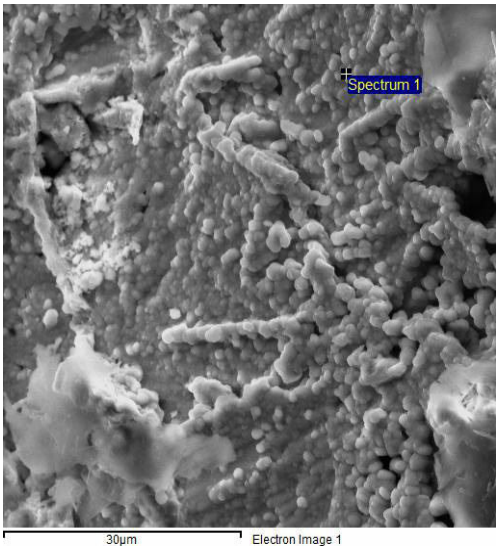
Figure 1. Metamorphic host rock suite: gneiss (left) and amphibolite (right), both comprising clearly visible clinozoisite grains

Samples were collected in which there was a visible occurrence of small crystals of titanite from the pegmatite body from the locality Dunje, and they were examined with the SEM-EDS technique in the laboratory Ambicon at the University in Stip.

Scanning electron microscopy analyses and electron micro-photographs were conducted using a VEGA3LMU scanning electron microscopy (SEM) increasing 2×1000 000, Wwire, voltage up 200 V to 20 kV, infrared camera, maximum sample size 81 mm height, 30 mm width. The study utilized semi-quantitative analysis using appropriate standards. The standards used are as follows: O: SiO_2; Na: albite; Mg: MgO; Al: Al_2O_3; Si: SiO_2; P: GaP; Ca: wollastonite; Ti: Ti; Fe: Fe; Br: KBr.

RESULTS AND DISCUSSION

The examinations performed by means of electron microscopy on the samples of the pegmatite wire near the village of Dunje are shown in Figs. 2-7. The manner of appearance of rutile, its chemical composition, as well as the EDS spectrum are shown (Figs. 2-5). From the results shown, it can be seen that rutile occurs in fine-grained aggregates, and it occurs at the very base of the sample. In the chemical composition of the rutile there is a certain concentration of Fe and P, which clearly speaks of the processes of geochemical substitution that occur on the mineral rutile itself. In Figs. 6 and 7, titanite investigations are shown. From the presented data, it can be noticed that titanite occurs in regular crystallographic shapes and that its composition is approximately corresponding to the stoichiometric composition of titanite. From the photographs it is clear that these are two generations of minerals: the first generation (rutile) appearing at the very base of the sample and it occurs in fine-grained crystalline aggregates, and the second generation (titanite) appearing over the first generation, in larger crystal shapes that have regular crystallographic shapes.



Element	Weight %
O K	37,16
Al K	1.50
P K	1.66
Ti K	58.20
Fe K	1.48
Totals	100.00

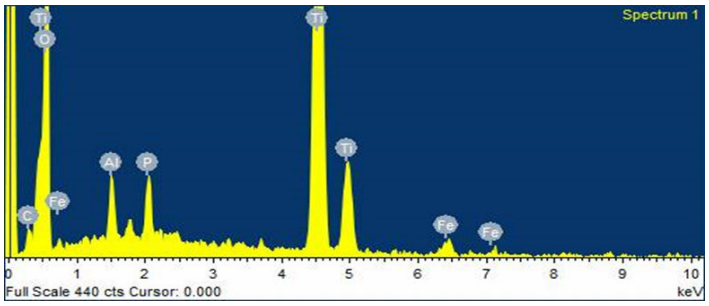


Figure 2. SEM-EDS results (photograph and spectral analysis) of rutile from Dunje

Element	Weight %
O K	42.36
Al K	1.33
Si K	1.05
P K	1.77
Ca K	0.41
Ti K	51.45
Fe K	1.63
Totals	100.00

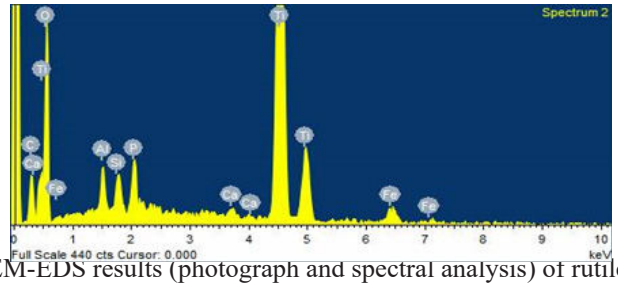
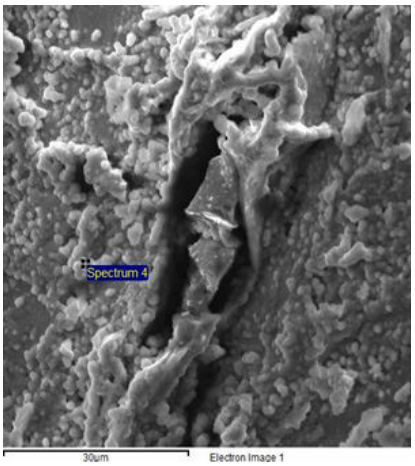


Figure 3. SEM-EDS results (photograph and spectral analysis) of rutile from Dunje



Element	Weight %
O K	44.01
Al K	1.64
Si K	0.50
P K	2.11
Ti K	50.30
Fe K	1.44
Totals	100.00

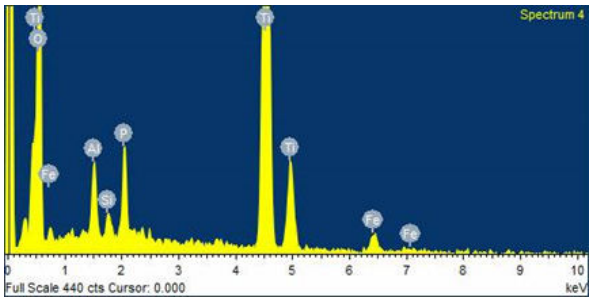
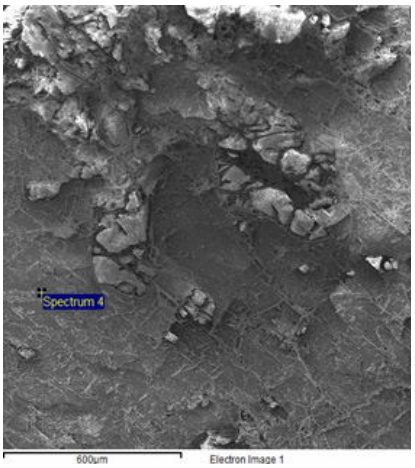


Figure 4. SEM-EDS results (photograph and spectral analysis) of rutile from Dunje



Element	Weight %
O K	42.91
Al K	1.38
Si K	0.52
P K	1.82
Ti K	51.88
Fe K	1.49
Totals	100.00

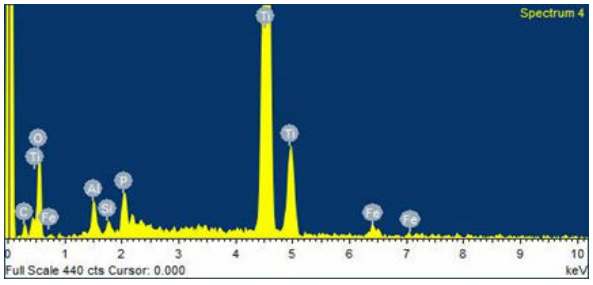
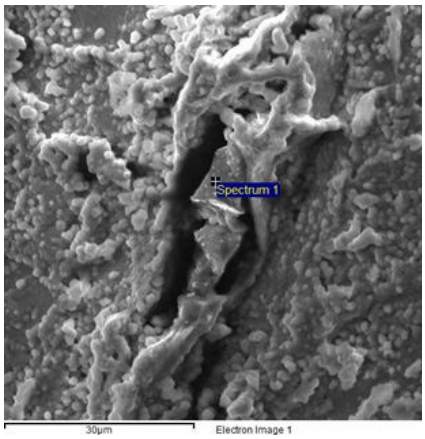


Figure 5. SEM-EDS results (photograph and spectral analysis) of rutile from Dunje



Element	Weight %
O K	51.94
Si K	12.78
Ca K	18.73
Ti K	16.55
Totals	100.00

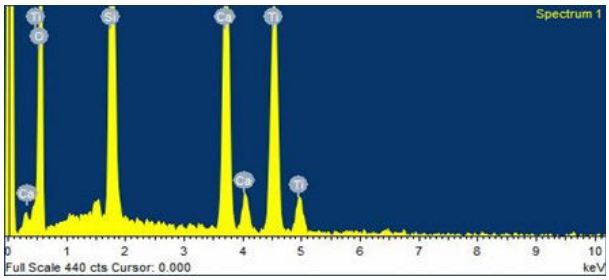
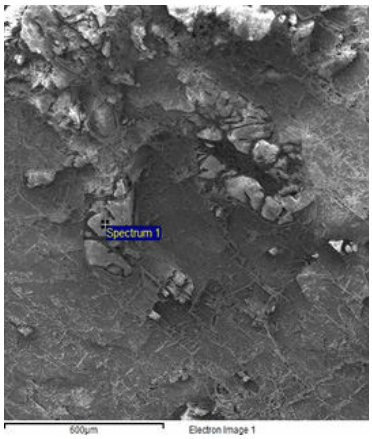


Figure 6. SEM-EDS results (photograph and spectral analysis) of titanite from Dunje



Element	Weight %
O K	47.07
Si K	13.16
Ca K	21.74
Ti K	18.03
Totals	100.00

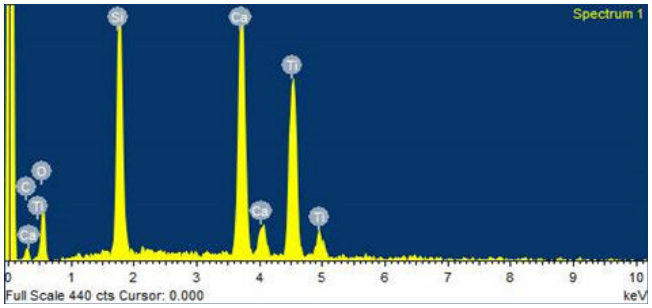


Figure 7. SEM-EDS results (photograph and spectral analysis) of titanite from Dunje

CONCLUSION

In the Pelagonian metamorphic complex, in the vicinity of the village Dunje, at the contact between the gneisses and the granites, there is a pegmatite wire in which a large number of minerals appear: albite, microcline, amphibole, epidote, titanite, quartz, muscovite, chlorite, stilbite, heulandite, pyrite, apatite, and

rutile. The paper presents the tests performed using the SEM-EDS technique on a sample in which the association rutile-titanite appears. The results of the experiments show that rutile appears as the first generation, while titanite appears as the second generation. If we take into account the age of the pegmatites within the sites of Caniste and Dunje [18], which, based on the age of zircon, is determined to be 250 MA, it can be concluded that, within the metamorphic evolution of the Pelagon [19], there are metamorphic processes that have also affected the occurrence of pegmatites. The appearance of two generations of minerals such as rutile and titanite, of which rutile appears basically in fine-grained aggregates and titanite appears as the second generation in larger crystalline forms, clearly speaks of metamorphic processes with the presence of a fluid phase that was rich in Ca, P, Fe, and Si [20,21].

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СЕМ-ЕДС ИСПИТУВАЊА НА ПЕГМАТИТСКАТА ЖИЦА-ДУЊЕ (ПЕЛАГОНИСКИ МЕТАМОРФЕН КОМПЛЕКС) ПОЈАВА НА ТИТАНИТ НА ОСНОВА ОД РУТИЛ

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Резиме

Во пегматисткото тело на локалитетот Дуње (Пелагониски метаморфен комплекс) испитувана е асоцијата рутил-титанит со примена на SEM-EDS методата и притоа е одредено дека рутилот се појавува како прва генерација во рамките на метаморфната еволуција на пелагонот, додека титанитот се појавува како втора генерација како резултат на метаморфно-метасоматските процеси во присуство на флуидна фаза богата со Ca, Fe, P, Si.

Клучни зборови: *титанит, рутил, пегматит*