351
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CONTRIBUTION TO THE WIDENING AND CONFIRMATION OF THE MINERAL ASSOCIATION IN THE BOROV DOL ORE DEPOSIT, BASED ON SEM ANALYSIS

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Abstract: The latest mineralogical study of the Borov Dor copper porphyry deposit have selected a total of 6 representative samples from 4 exploration drill holes and treated in laboratory conditions with a study under optical polarization microscope and a scanning electron microscope (SEM). Six representative pairs of monomineral and polymineral parageneses were identified and their chemical compositions with their associated minerals were determined, too. Quartz-chalcopyrite-sulfide paragenesis stands out as dominant and mainly chalcopyrites are very close their theoretical compositions. Within simple sulphide paragenesis come quartz-pyrite-chalcopyrite in which pyrite is dominant with compositions that are also close to theoretical. Chalcopyrite-bornite paragenesis stands out as transformation one during the decay of the solid solution, where the lattice structure of the bornite in the corroded chalcopyrite predominates. The compositions show a tendency of transition in both chalcopyrite and bornite directions and defectivness is observed. In a similar constellation are the solid solution decays in the chalcopyrite-cubanite pair where the compositions of both interaction minerals have undergone modification, but clearly indicate the transformation phase. Even more characteristic is the transformation phase in chalcopyrite-bornite-idaite where the transitions are gradual and the mixed phases defective to allowable level. This sequence of transformations ended with the tetrahedra-tenantite phases with multiple variants. Of particular note is the quartz-molybdenite phase with pure molybdenite rod-like forms as a representative of higher temperature mineral paragenesis.

Key words: ore minerals; mineral association; porphyry copper deposit; scanning electron microscope

INTRODUCTION

Borov Dol porphyry copper deposit is located in the southern part of the Bucim-Damjan-Borov Dol ore district, in the areas that belong to the Vardar zone. The volcanic caldera hosting this deposit is 5 km across being well developed in the district morphostructure. The caldera is complicated by several domes and depressions (1.0 – 1.5 km in diameter), one of which hosts the Borov Dol deposit. The ore field is crossed by NW extending faults with associated Neogene latite to quartz–latite dikes, necks and lava extrusions. Ore enclosing volcanics are altered by hydrothermal processes. The Borov Dol deposit, which serves as a successor deposit for the Buchim deposit within the Buchim mine, was discovered in 1930, when boreholes recovered copper mineralization with contents of 0.2 – 0.7% Cu. Excavations in this area date back to World War II, but detailed geological exploration began in 1966 and, with some interruptions, is being carried out to this day. The ore reserves of the deposit were estimated by thorough systemic exploration in 1973–1977 to be 40 000 000 t with average Cu and Au concentrations of 0.3% and 0.28 g/t, respectively. The reserves were confirmed one more time in 2015 with the new Elaborate (Petrov et al., 2015). During the geological explorations continuous laboratory investigations and studies of the deposit have been performed, and the results are presented in the works of Veličković and Tudžarov (1978), Culev (1978), Culev et al. (1984), Mitevski and Culev (1986), Serafimovski (1990), Serafimovski et al. (1993), Serafimovski et al. (1996), Serafimovski et al. (2010) etc.

With the latest laboratory studies, the results of which are presented in this paper, special emphasis is placed on the study of the mineral composition and the paragenetic relationship of the deposit, which is very important for a more reliable interpretation of the ore formation conditions, the possibility of location, components, as well as for finding adequate technical and technological solutions for further explorations. This is all the more significant given that most porphyry deposits are characterized by polymetallic character and complex mineral association, which is characteristic of the Borov Dol deposit, too. Based on previous investigations carried out by Atanasov (1977), Ivanov and Serafimovski (1984), as well as the latest scanning electron microscope study, the Borov Dol deposit has been characterized by complex and diverse ore minerals: pyrrhotite, chalcopyrrhotite, pyrite, native gold, petzite, magnetite, rutile, sphene, anatase, hematite, specularite, martite, molybdenite, chalcopyrite, cubanite, valerite, bornite, tetrahedrite-tennantite (fahlore), sphalerite, chalcocite, rose chalcocite, siderite, limonite, tenorite etc. Quartz and calcite are the most common companions of ore-derived minerals from the unprocessed minerals. It should be noted that most of the listed ore minerals occur only as mineralogical occurrences and do not have any major significance to the ore deposit. This conclusion can be seen from the following review. The latest mineralogical study was performed in 2014 and 2017 (Serafimovski and Tasev, 2014; 2017), where have been confirmed the most of the ore minerals and in the deposit paragenesis were enclosed specularite, limonite, goethite etc.

MATERIALS AND METHODS

Within the current ore minerals study of the Borov Dol ore deposit were analyzed six samples (that have proven as the most promising) taken from cores of 4 exploration drill holes (BD24, BD310, BD335 and BD338). From the samples were prepared six polished sections that were previewed on the polarizing optical microscope Zeiss Axiolab Pol in reflected light mode. The most interesting mineral assemblages were subjected to further study. Namely, the chemical compositions of the major mineral phases were determined by scanning electron microscope (SEM). The SEM analyses were recorded on the scanning electron microscopy VEGA3 LMU and INCA Energy 250 Microanalysis System, located at the “Goce Delčev” University in Štip, for quantitative analyses of the samples. The SEM analyses were performed with the SE (Scattered Electrons) detector on 20 kV voltage. First, the samples were cleaned and then a small piece was put on the sample holder with carbon double adhesive tape on it. The sample’s surface was coated with gold on Modular Coater, Quorum Q150R ES and then analyzed in high vacuum mode with more than 0.018 Pa. The sample surface was motorized on 5 axes (*x*-*y*-*z*, rotation and tilt). For SEM, the VegaTC software was used. The energy dispersive X-ray (EDX) system for SEM is a fully quantitative SDD with excellent performance at low and high count rates, which is capable of achieving a resolution better than 125 eV on the MnK_{α}, FK_{α} and CK_{α} peaks. The working distance for X-ray was 15 mm. The detector control and data acquisition were done with INCA software. The SEM-EDS analyses were done on the unpolished surfaces.

RESULTS AND DISCUSSION

The mineral association at the Borov Dor porphyry deposit has been studied for a long time since the mid-20th century, but as geological research progressed so did mineralogical investigations, mainly with polarizing optical microscopes and only occasionally by electron microprobe. In our latest study, the results of which are presented in this paper, a study at optical polarization microscope and scanning electron microscope have been used. The samples within this paper are representative and taken from the latest exploration boreholes, drilled during 2016 and 2017. A big number of polished ore sections have been examined and several interesting paragenes have been identified whose mineral phases are later analyzed by scanning electron microscopy. This is primarily pure sulfide paragenesis in which the chalcopyrites occupy a dominant position on the one hand and the pyrites on the other hand, followed by interesting breakdown of a solid solution in the form of chalcopyrite-bornite paragenesis, which further proceeds also with the dissolution of a solid solution including chalcopyrite, cubanite and idaite. They are very specific for the intermediate-temperature levels of the formation in the deposit, and then the sequence of newly formed mineral phases continues with complex sulfosalt parageneses dominated by enargite, famatinite, tetrahedrite, tennantites etc. To this entire association should be added isolated but clearly present and determined sulfide mineral phases of simple sulfides dominated by molybdenite and large crystalline galena. The precisely noted mineral phases under an optical microscope were analyzed under the scanning electron microscope, where they were largely confirmed for which the compositions of the individual minerals and mineral phases were obtained. It should be emphasized here that we have noticed mixing processes of compositions between the individual pairs, which especially were expressed in the chalcopyrite-bornite pairs and the mineral phases of the tetrahedrite-tennantite (fahlore) group. The following are the results of the scanning electron microscope analyses with characteristic photographs and positions of the measurements performed, while the tables present the chemical composition of the determined mineral phases.

At the next Figure 1a, chalcopyrite and bornite aggregates are shown, which compositions further were determined by scanning electron microscope analysis (Figure 1b), and the results are presented in Table 1.

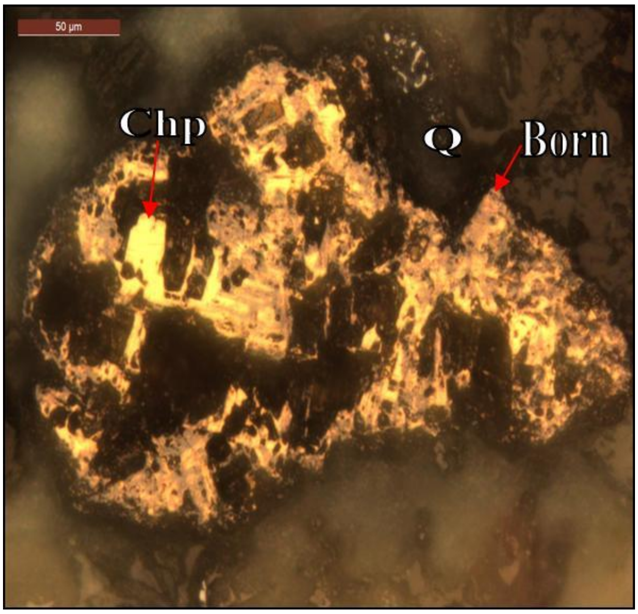

Fig. 1a. Morphology of lamellar chalcopyrite-bornite aggregate, intensively corroded and relictized. Parallel Nichols, magnif. × 630 *II*

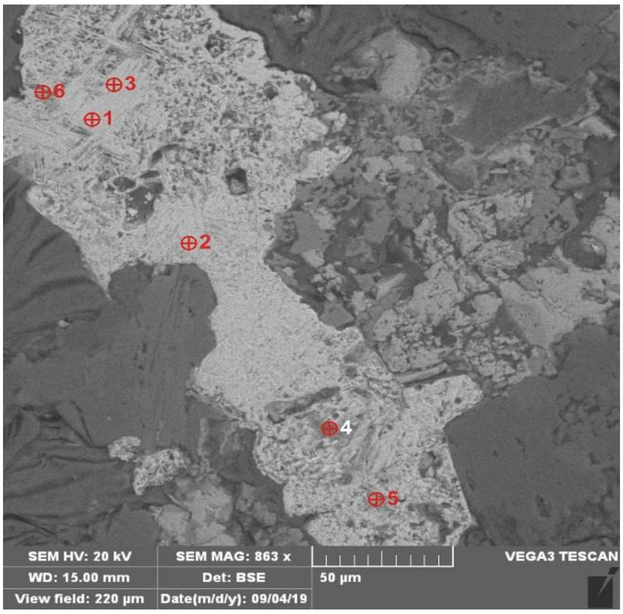

Fig. 1b. Positions of performed analyses under the SEM

Table 1

SEM analysis results of chalcopyrite-bornite aggregate (%wt)

Sample point	S	Fe	Cu	Total
Spectrum 1	31.30	20.94	47.76	100.00
Spectrum 2	30.29	21.67	48.04	100.00
Spectrum 3	32.55	23.49	43.95	100.00
Spectrum 4	17.00	20.09	62.90	100.00
Spectrum 5	23.46	19.42	57.11	100.00
Spectrum 6	27.75	18.04	54.71	100.00

Chalcopyrite is the most common and the most important ore mineral in regards to copper mineralization of this particular deposit. Within this analyzed mineral aggregate we have determined that we are dealing with chalcopyrite-bornite intergrowths.

The replacement of primary chalcopyrite grain by the bornite lamellae-like grains probably is still unfinished process based on their respective chemical compositions, which are between the representative compositions of both minerals. Chalcopyrite-bornite intergrowths as these were found in many typical primary copper sulfide ores and are believed to have formed by bornite replacing chalcopyrite (Ramdohr, 1980; Robb, 2005). As it has been proven (Amcoff, 1988), the solid-state replacement of chalcopyrite by bornite occurred in a hydrothermal interval of temperatures (200 – 500^{O}C) when chalcopyrite very likely reacted with chalcocite to form bornite under reducing conditions.

Figure 2a depicts a microscopic image of a single relic and well-developed pyrite aggregate that was further subjected to scanning electron microscopy analysis, which determined its composition and admixtures. The photograph with the scans of the scanning electron microscope is shown in Figure 2b, and the results are presented in Table 2.

Pyrite, along with chalcopyrite, is the most abundant ore mineral in the Borov Dol deposit. We would like to stress that the most often it occurs in the form of allotriomorphic grains, granular aggregates (ranging from a few microns to 1.5 mm) and in the form of thin veins and veinlets.

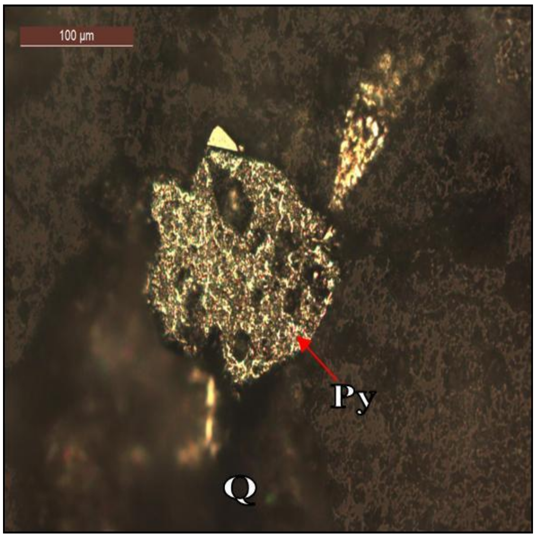

Fig. 2a. Microphoto of a single relic and well-developed pyrite aggregate. Parallel Nichols, magnif. × 200 *II*

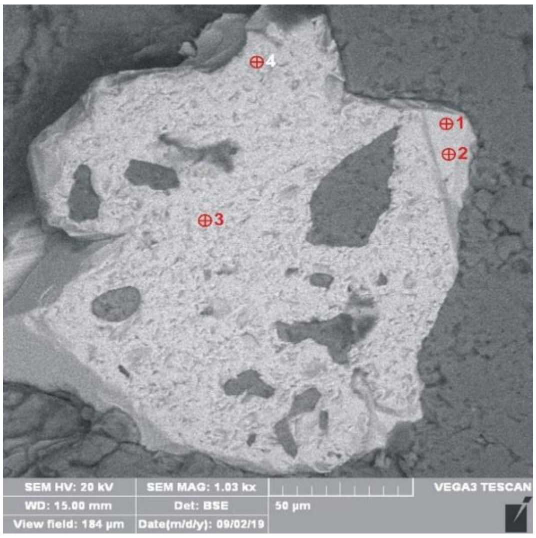

Fig. 2b. Positions of performed analyses under the SEM

Table 2

SEM analysis results of pyrite from the Borov Dol deposit **(%wt)**

Sample point	S	Fe	Cu	Au	Total
Spectrum 1	55.94	44.06	–	–	100.00
Spectrum 2	54.25	45.33	–	0.64	100.00
Spectrum 3	53.84	46.08	0.08	–	100.00
Spectrum 4	57.12	43.26	–	–	100.38

The manifested presence of gold within pyrite from the Borov Dol deposit (Spectrum/analysis 2) is not uncommon and probably can suggest that analyzed mineral grain belongs to the first generation pyrite (Serafimovski et al., 1993).

In the following Figure 3a, details of chalcopyrite with possible exsolution of sulfosalts are analyzed on a scanning electron microscope which showed that chalcopyrite builds a decay pair of solid solution with cubanite. The microphotograph is shown in Figure 3b while the results of the SEM analysis are given in Table 3.

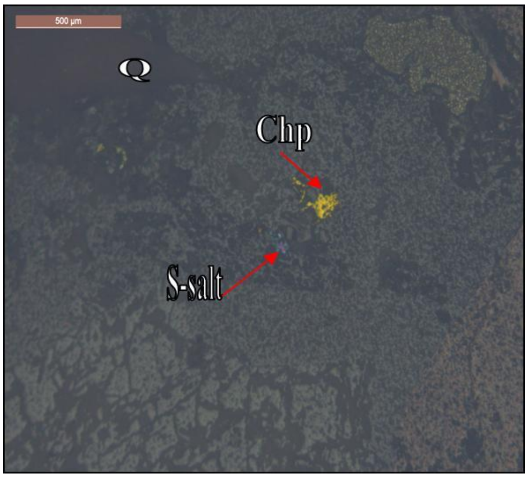

Fig. 3a. Microphoto of a single relic chalcopyrite grain and small sulfosalt phase grain.
Parallel Nichols, magnif. × 200 *II*

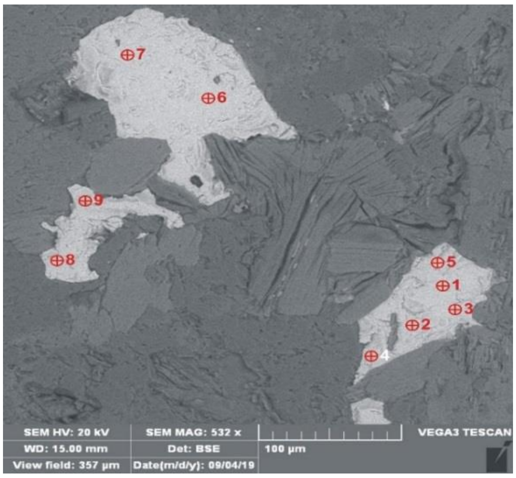

Fig. 3b. Positions of performed analyses under the SEM of the chalcopyrite-cubanite assemblage

Irregularly shaped masses of cubanite are found (Spectrum 8), but also chalcopyrite and cubanite form intergrowths of laths or bands of each mineral.

Table 3

SEM a nalysis results of chalcopyrite-cubanite (%wt)

Sample point	S	Fe	Cu	Total
Spectrum 1	36.08	30.17	33.75	100.00
Spectrum 2	36.16	29.94	33.89	100.00
Spectrum 3	36.41	31.13	32.47	100.00
Spectrum 4	33.91	36.32	29.77	100.00
Spectrum 5	36.59	30.66	32.75	100.00
Spectrum 6	37.23	30.32	32.45	100.00
Spectrum 7	31.76	32.78	35.47	100.00
Spectrum 8	29.95	43.66	26.40	100.00
Spectrum 9	28.82	38.25	32.93	100.00

The solid solution which was very rich in iron as compared with pure chalcopyrite, on cooling unmixed with the segregation of chalcopyrite and cubanite. The most probably it results (cubanite) from exsolution from chalcopyrite at temperatures below 200 to 210 °C (Ramdohr, 1960).

The following Figures 4a and 4b provide microscopic photographs of molybdenite rod-like grains of various orientations, but essentially uniform. These molybdenite rods are analyzed on a scanning electron microscope, with microphotographs with the sites of analysis performed in Figures 4c, d and e, while the composition of molybdenum with the admixture elements is shown in Table 4.

Molybdenite occurs ore as fine disseminations and thin veinlets hosted in quartz veins and veinlets. The dispersed fine (a few to a few tens of micrometers) molybdenite disseminations in quartz veins, most likely, are the earliest, whereas massive veinlet-like intergrowths of larger (a few tenths of a millimeter to 1.5 mm) flakes belong to the second generation and intersect early sulfides and accompanying quartz. Molybdenite occurrence is of low intensity, although sometimes it is intensive, which is very similar to findings of Serafimovski et al. (1993).

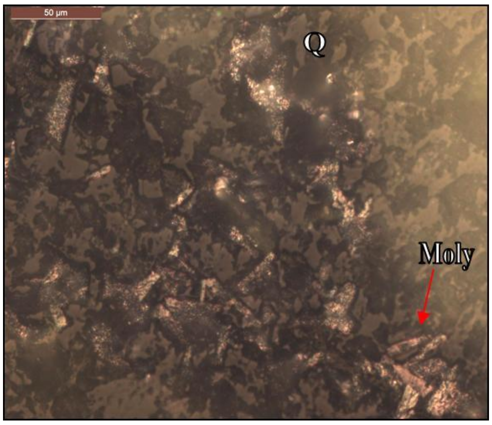

Fig. 4a. Microphoto of a rod-like molybdenite aggregate in quartz-molybdenite vein. Parallel Nichols, magnif. × 400 *II*

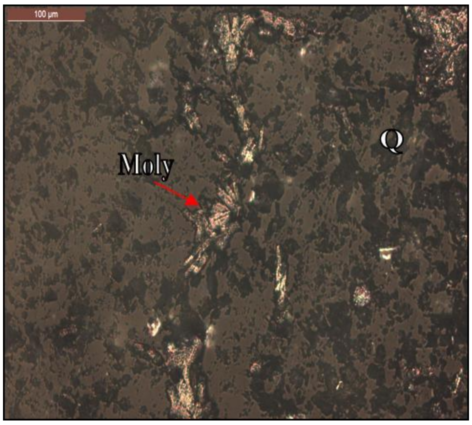

Fig. 4b. Microphoto of a discontinued quartz-molybdenite vein with radial-ray like molybdenite rods. Parallel Nichols, magnif. × 200 *II*

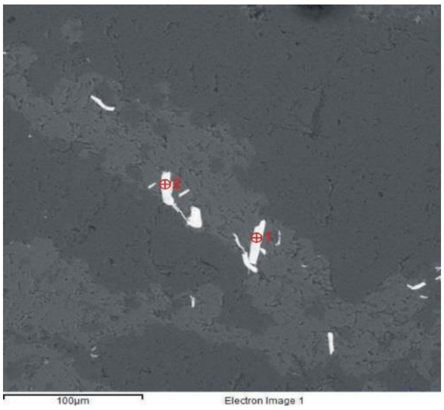

Fig. 4c. Positions of performed analyses under the SEM, detail 1

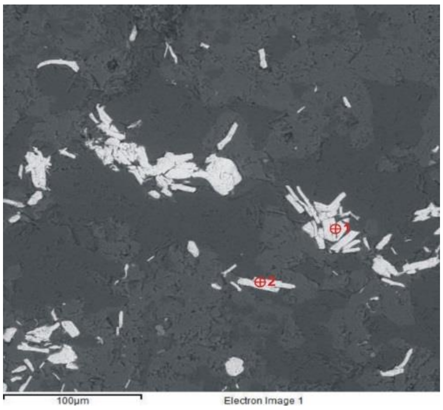

Fig. 4d. Positions of performed analyses under the SEM, detail 2

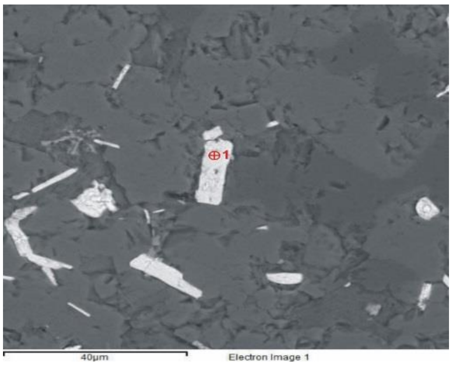

Fig. 4e. Positions of performed analyses under the SEM, detail 3

Table 4

SEM analysis results of molybdenite grains ***(%wt)***

Sample point	S	Mo	Cu	Ag	Fe	Total
Spectrum 1	37.49	61.44	0.35	0.22	0.50	100.00
Spectrum 2	38.22	60.74	0.28	0.18	0.58	100.00
Spectrum 1 det 2	38.87	60.01	0.42	0.15	0.55	100.00
Spectrum 2 det 2	37.66	61.20	0.45	0.20	0.49	100.00
Spectrum 1 det 3	37.43	61.57	0.25	0.25	0.50	100.00

According to scanning electron microscope analysis, the composition of molybdenite, irrespective to its morphology and dimensions, varies within a narrow range of 60.01–61.57 %wt Mo and 37.43–38.87 %wt S, which is slightly different from the ideal composition of 59.94% Mo and 40.06% S and in favor of molybdenum concentrations. Also, there were noticed certain concentrations of elements such are copper, silver and iron as associates of the molybdenite geochemical association within the porphyry copper deposits as the Borov Dol is in its nature.

Molybdenite was likely deposited as a result of multiple crystallization; numerous intersections with displacement of similar in appearance quartz-molybdenite veins and veinlets are observed (Figure 4c). In addition, the quartz–molybdenite veinlets are crosscut by quartz-sulfide veinlets. *The quartz-molybdenite stage* is distinguished on the basis of crosscut relationships of quartz-molybdenite veins and veinlets with products of high temperature alteration pertaining to the preore stage. The early quartz-molybdenite assemblage 4 (Figures 4c and 4d) is expressed in quartz and quartz-molybdenite veinlets.

At the following Figures 5a and 5b are shown individual large chalcopyrite to chalkopyrite-bornite aggregates within a silicified rock matrix that were further subjected to scanning electron microscopy (Figures 5c, d, e, f) for the purpose of determining their chemical composition (Table 5).

Our analyses have shown that within this complex chalcopyrite-bornite aggregate occur compound that Frenzel (1958a, 1958b) during his study of natural bornite in the process of decomposition couldn't analyze because of the small amount present in his sample. Later on that compound idaite was described as a supergene sulfide which is formed by the alteration of bornite by oxidation. That statement was confirmed by Ramdohr (1960), who had observed idaite from hundreds of localities and pointed out that in each instance the idaite is the first oxidation product of bornite (Olson, 1982). Ours analysis confirmed presence of idaite at least in two positions (Spectrum 3 detail 2 and Spectrum 5 detail 2) along bornite matrix resulting from decomposition of chalcopyrite (Spectrum 1–3 detail 3).

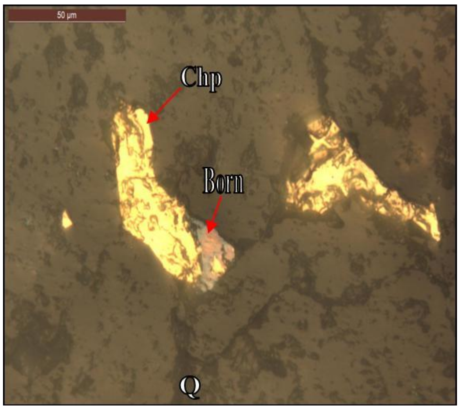

Fig. 5a. Microphoto of an individual massive chalcopyrite to chalcopyrite-bornite aggregate within silicified matrix. Parallel Nichols, magnif. × 630 *II.*

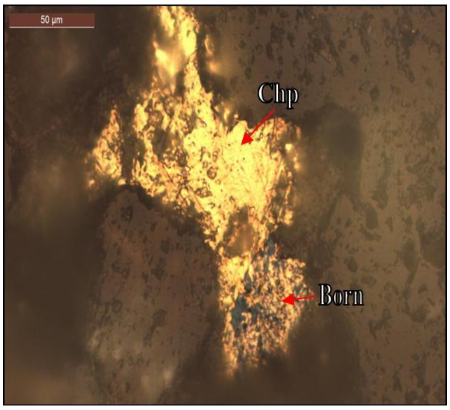

Fig. 5b. Microphoto of coarse-grained and intensively corroded chalcopyrite-bornite aggregate within silicified cavity. Parallel Nichols, magnif. × 400 *II.*

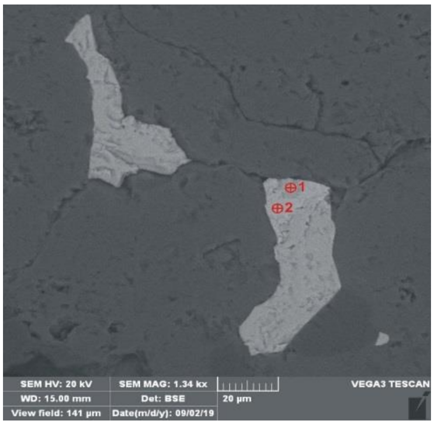

Fig. 5c. Positions of performed analyses under the SEM, detail 1

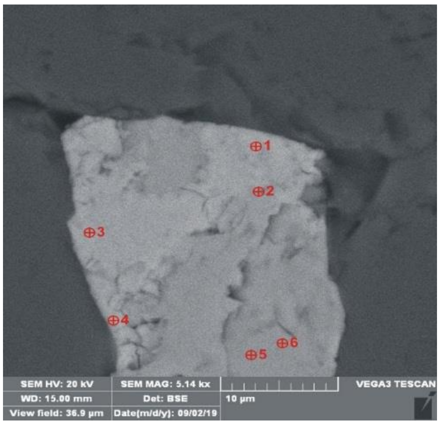

Fig. 5d. Positions of performed analyses under the SEM, detail 1a

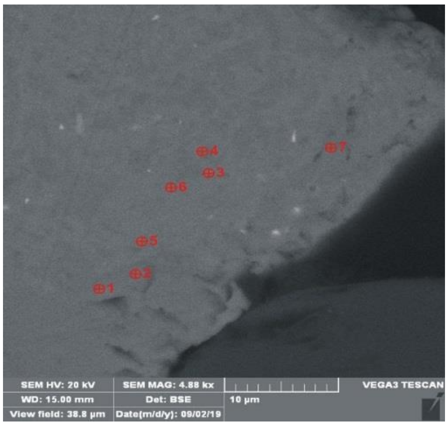

Fig. 5e. Positions of performed analyses under the SEM, detail 2

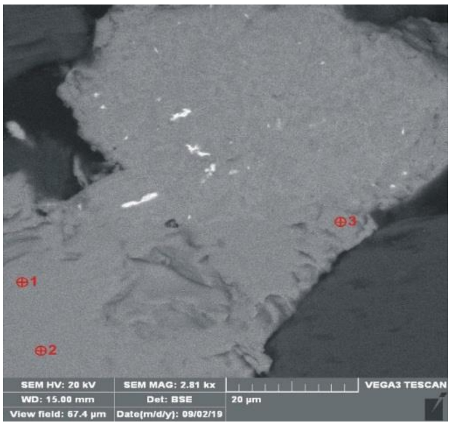

Fig. 5f. Positions of performed analyses under the SEM, detail 3

Table 5

SEM analysis results of sample 20 (%wt)

Sample point	S	Fe	Cu	Total
Spectrum 1	37.11	28.95	33.94	100.00
Spectrum 2	28.46	12.23	59.31	100.00
Spectrum 1 det 1a	26.48	6.54	66.98	100.00
Spectrum 2 det det 1a	27.15	11.35	61.50	100.00
Spectrum 3 det 1a	29.94	14.26	55.79	100.00
Spectrum 4 det 1a	31.18	7.50	61.32	100.00
Spectrum 5 det 1a	38.23	28.07	33.70	100.00
Spectrum 6 det 1a	37.40	27.24	35.36	100.00
Spectrum 1 det 2	37.13	28.62	34.25	100.00
Spectrum 2 det 2	36.67	28.38	34.95	100.00
Spectrum 3 det 2	37.89	5.78	56.33	100.00
Spectrum 4 det 2	36.03	14.98	48.98	100.00
Spectrum 5 det 2	36.80	4.40	58.81	100.00
Spectrum 6 det 2	34.37	17.77	47.86	100.00
Spectrum 7 det 2	36.01	27.22	36.77	100.00
Spectrum 1 det 3	37.95	29.49	32.56	100.00
Spectrum 2 det 3	36.84	29.33	33.84	100.00
Spectrum 3 det 3	36.79	28.60	34.61	100.00

At the following Figures 6a and 6b, are shown individual large fahlore (tetrahedrite-tennantite), galena, chalcopyrite and associated mineral aggregates, respectively. Details that were further subjected to scanning electron microscopy are shown in Figures 6c and 6d while their determined respective chemical compositions are shown in Table 6.

Fahlore dominates among sulfosalts, mainly as aggregates of grains and small (< 0.*n* mm) crystals. Fahlore mostly belongs to the tetrahedrite–tennantite series, leaning towards tetrahedrite representatives (Table 6). Fe-Zn-bearing varieties are predominant. Ag generally is absent or within low concentrations. Some fahlore grains reveal oscillatory zoning caused by varying Sb and As contents and enrichment in Sb from the center outward up to the appearance of pure tetrahedrite. Fahlores determined within the Borov Dol porphyry copper deposit were found in a complex mineral assemblage composed of fahlores + galena + sphalerite + chalcopyrite + pyrite, which is quite similar to findings of some other researchers for some other deposits within the well-known Lece-Chalkidiki zone, the Tulare-Kiseljak ore deposit (Serafimovski et al., 1991) and the Buchim ore deposit (Serafimovski et al., 2016).

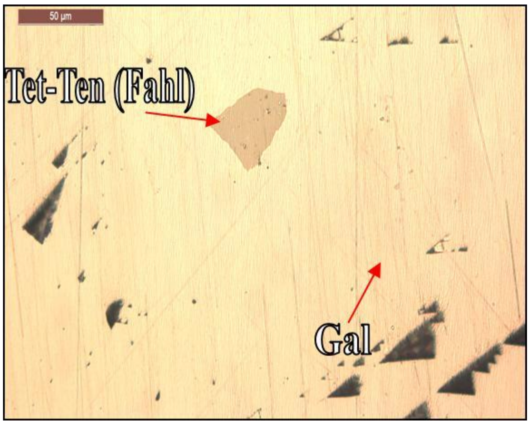

Fig. 6a. Microphoto of an individual massive tetrahedrite-tennantite aggregate within massive galena. Parallel Nichols, magnif. × 200 *II.*

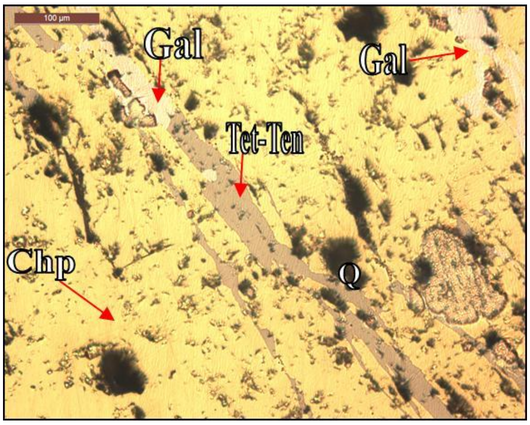

Fig. 6b. Microphoto of veinlet-stockwork tetrahedrite-tennantite aggregate within massive chalcoyrite anclosing galena relics. Parallel Nichols, magnif. × 200 *II*

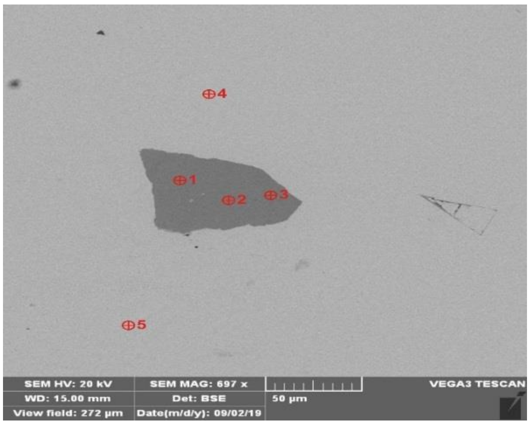

Fig. 6c. Positions of performed analyses under the SEM, detail 1

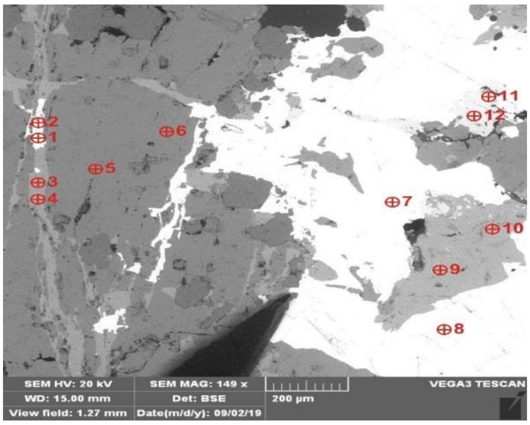

Fig. 6d. Positions of performed analyses under the SEM, detail 2

Table 6

SEM analysis results of sample 13 ***(%wt)***

Sample point	S	Fe	Cu	Zn	As	Ag	Sb	Pb	Total
Spectrum 1	27.25	4.92	33.01	4.65	0.74	0.85	27.47	1.11	100.01
Spectrum 2	26.87	5.42	31.99	4.22	1.02	0.83	28.84	1.31	100.50
Spectrum 3	28.09	4.12	32.91	6.05	3.09	0.90	22.99	1.85	100.00
Spectrum 4	14.55	–	–	–	–	–	–	85.45	100.00
Spectrum 5	16.40	–	–	–	–	–	–	83.60	100.00
Spectrum 1 det 2	19.30	5.59	5.39	–	–	–	0.63	69.09	100.00
Spectrum 2 det 2	19.52	5.72	5.36	–	–	–	0.94	68.46	100.00
Spectrum 3 det 2	29.10	6.49	37.07	5.37	4.87	–	17.10	–	100.00
Spectrum 4 det 2	29.05	6.56	36.07	4.84	2.88	.–	20.60	–	100.00
Spectrum 5 det 2	37.03	29.21	33.76	–	–	–	–	–	100.00
Spectrum 6 det 2	38.99	29.20	31.65	–	0.16	–	–	–	100.00
Spectrum 7 det 2	18.06	–	–	–	–	–	–	81.94	100.00
Spectrum 8 det 2	15.88	–	1.25	–	–	–	–	82.87	100.00
Spectrum 9 det 2	28.45	2.73	34.85	5.23	1.75	–	27.00	–	100.01
Spectrum 10 det 2	25.49	4.27	35.68	6.09	1.42	–	26.06	1.01	100.02
Spectrum 11 det 2	28.60	1.16	39.94	–	–	–	28.90	1.40	100.00
Spectrum 12 det 2	28.37	1.45	40.69	1.51	–	–	27.29	0.75	100.06

Certain analyses within this mineralized sample have proved existence of famatinite (Spectrum 11 and 12 of detail 2 in sample 13). This is in great agreement with finding that Fe-Zn tetrahedrite-tennantite (fahlore) sometimes shows replacement textures containing a newly formed mineral assemblage (in our case famatinite), resulting from fahlore breakdown (Krismer et al., 2011; Krismer and Tropper, 2013). The mineralogical composition of the reaction domains is highly variable. This occurrence can be attributed to a presence of structurally disordered crystals that produced intergrowth of the famatinite series of minerals as it was suggested by Pósfai and Sundberg (1998). Up to date, findings (Pósfai and Buseck (1998) suggest that coexisting fahlore and famatinite are non-equilibrium assemblages and resulting from certain effects of fluctuations in the bulk Sb content.

Galena occurs as clusters of large (up to 3 cm) crystals as well as fine-grained aggregates. The galena minerals sometime host tetrahedrite-tennantite mixed minerals (Figure 6a). The majority of galena grains did not contained some additional microinclusions of Ag as it is usual for some other porphyry deposits elsewhere (Kovalenker et al., 2011). But, however, two analyses have shown that galena was strongly affected by the presence of iron (5.54–5.72 %wt Fe), coper (5.36–5.39 %wt Cu) and antimony (0.63–0.94 %wt Sb).

CONCLUSION

Recent study presented within this paper have defined the composition of major sulfide minerals and a series of sulfosalt in the Borov Dol ore deposit.

The simple sulfides of the type of chalcopyrite, pyrite, molybdenite, galenite, etc., show stability and their composition obtained by these analyses generally does not deviate much from the theoretical compositions for those mineral phases.

Transforming pairs of typical decay of a solid solutions such are chalcopyrite-bornite and chalcopyrite-bornite-cubanite show their own characteristics. The compositions of these newly formed phases and the host mineral, in this case, the chalcopyrites show a tendency to alter and deviate from their theoretical values. This is at best dependent on the extent of the transformation and therefore we have deviations that still define the newly created phase within their boundaries, such as bornite and cubanite in this case.

Sulfosalt paragenesis of the chalcopyrite-bornite-idaite type has been defined where continuous transformation processes did not complete and created mixed phases with defective compositions that still characterize major phases. A similar, but more pronounced, case is the mineral paragenesis of the tetrahedrite-tennantite sequence, where the transitions can be traced precisely on the basis of the obtained compositions ranging from pure tetrahedrite to halfway to the tennantite phase, but a pure tennantite phase is not defined. This sequence is part of a more complex sulfosalt paragenesis that is defined as quartz-enargite-luzonite-famatinite-tetrahedrite-tennantite, where the famatinites are also defined by a composition corresponding to that mineral phase.

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Резиме

ПРИЛОГ КОН ПРОШИРУВАЊЕ И ПОТВРДУВАЊЕ НА МИНЕРАЛНАТА АСОЦИЈАЦИЈА ВО РУДНОТО НАОЃАЛИШТЕ БОРОВ ДОЛ ВРЗ БАЗА НА SEM-АНАЛИЗИТЕ

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Клучни зборови: рудни минерали; минерална асоцијација; порфирско бакарно наоѓалиште; скенирачки електронски микроскоп

Со најновите минералошки испитувања во порфирското бакарно наоѓалиште Боров Дол беа селектирани вкупно 6 репрезентативни примероци од 4 истражни дупнатини, 26и беа третирани во лабораториски услови со студиски оптички поларизационен микроскоп и со скенирачки електронски микроскоп (SEM). Беа констатирани шест карактеристични пара на мономинерални и полиминерални парагенези за кои е одреден и хемискиот состави заедно со нивните придружни минерали. Како доминантна се издвојува кварц-халкопирит-сулфидната парагенеза и халкопиритите главно имаат состав многу блиок до теоретскиот. Во проста сулфидна парагенеза доаѓаат кварц-пирит± халкопирит; во неа пиритите се доминантни со состав кој е исто така близок до теоретскиот. Халкопирит-борнитската

парагенеза се издвојува како трансформациона при распадот на цврст раствор, каде што решеткастата градба на борнитите во кородираните халкопирити доминира. Составот покажува тенденција на преод и кај халкопиритите и кај борнитите и се забележува дефектност. Во слична констелација е и распадот на цврст раствор во парот халкопирит-кубанит, каде што составот и на двата интерактивни пара претрпел корекции, но јасно ја назначува трансформационата фаза. Уште покарактеристична е трансформационата фазност кај халкопирит-борнит-идаитите каде преодите се постепени, а мешаните фази прифатливо дефектни. Оваа низа трансформации е крунисана со тетраедрит-тенантитските фази со повеќе варијанти. За посебно одбележување е кварц-молибденитската фаза со чисти молибденистски прачки како претставник на повисокотемпературната минерална парагенеза.