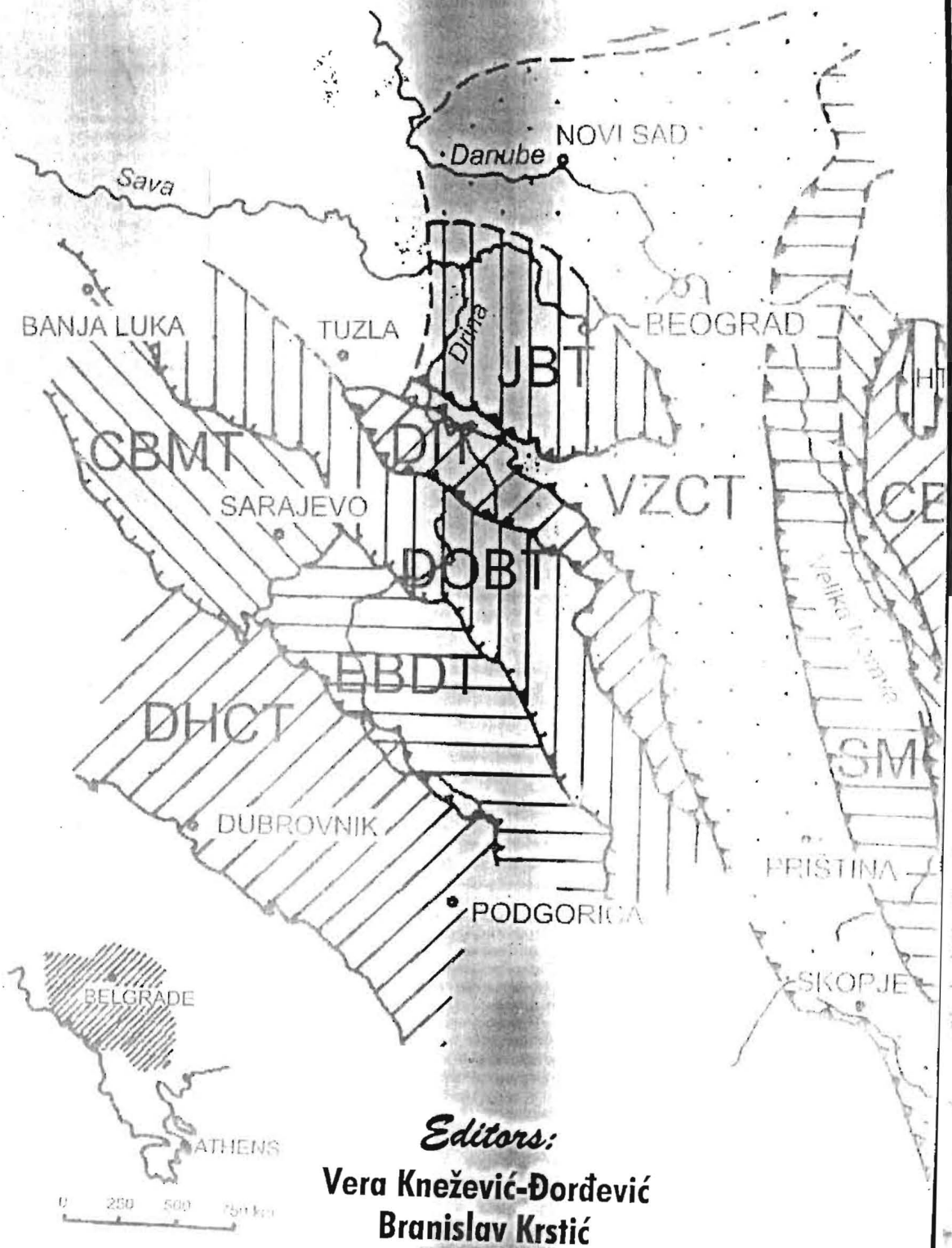
The Formation of the Geologic Framework of Serbia and the Adjacent Regions

Dedicated to Academic Stevan Karamata



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METALLOGENY OF THE KRATOVO-ZLETOVO VOLCANO-INTRUSIVE COMPLEX

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Abstract: *The Kratovo-Zletovo volcano-intrusive complex which occupies an area of 1200 km² has many specific features which are unique in the Balkan Peninsula and further afield. Intrusive, subvolcanic, volcanic and volcano-sedimentary facies were determined in it. It is calc-alkaline magmatism with well developed series in which dacite-andesite prevail. Its age was determined as Oligo-Miocene (16 to 32 m.y.) to Pliocene (in the basalts). Important deposits and occurrences of metals, non- metals and energy raw materials are related to this volcanic complex. It is characterized by the complex caldera structure*

Ore minerals are mainly located in the north-eastern parts of the complex, and within the Kratovo - Zletovo ore district. Hydro-thermal Vein type lead-zinc deposits prevail (Zletovo, Blizanci, Slegovo, Jamiste et al.). There are also stockwork-disseminated copper deposits (Plavica, Borovic, Tursko Rudari) and vein type (Zlatica), vein type uranium deposits - brecciated zones (Zletovska Reka) as well as gold mineralization related to the secondary quartzlites (Crni Vrv, Plavica). Native sulphur, quartzites, bentonites, jarosite, zoisites, alunites etc. deposits and occurrences were also found in the complex.

KEY WORDS: Metallogeny, ore mineralization, volcanic complex, Kratovo-Zletovo

1. INTRODUCTION

The Kratovo-Zletovo volcano-intrusive magmatic complex, also known in literature as the Kratovo-Zletovo volcanic area, is called "a complex" because of its numerous specific traits and varieties viewed from lithologic and structural-tectonic and metallogenetic aspects. The basic specific features of the complex are its numerous subvolcanic-volcanic and volcanogene-sedimentary members along with its polymetallic mineraliza-tion in which lead and zinc prevail.

Exploration and excavation of ores in these localities date from Roman period and intensified in the middle of the century. Today, there are many scientific papers which deal with the issues of lithology, volcanology, structures, magmatism and metallogeny of this volcanic complex. Important information about the magmatism and metallogeny can be found in the papers of PANTIĆ et al. (1972), IVANOV & DENKOVSKI (1978), RAKIĆ (1982), PETKOVIĆ (1982), BLEČIĆ (1983), STOJANOV & SERAFIMOVSKI (1990), SERAFIMOVSKI (1990, 1993, 1993 -b), BOEV et al. (1992), EFREMOV (1993), STOJANOV et al. (1995), SERAFIMOVSKI & ALEKSANDROV (1995), BOGOEVSKI (1995) et al. Recently, intensive exploration and investigation in gold deposits and occurrences, first of all those of epithermal type have been carried out. Positive results have already been reported.

2. METALLOGENIC FEATURES

The Kratovo-Zletovo ore district is located in the east-north-eastern parts of the Kratovo-Zletovo volcanic area. With its complex structural geological, and metallogenetic composition, it is one of the most significant regional ore-bearing units in the Lece-Chalkidiki zone (SERAFIMOVSKI, 1990).

The metallogeny of the Kratovo-Zletovo ore district is directly related to the evolution of the Tertiary intermediary (with variations from basic to acid) calc-alkaline magmatism represented mainly by volcanic (partly subvolcanic as well) facies of andesites, dacites, dacite-andesites, quartzlatites-ignimbrites, trachyandesites, trachytes, volcanic tuffs and breccias etc. Diorite porhyry and quartz-monzonite porphyry are the most common intrusive rocks. Spatially and paragenetically, this volcanism is related to important deposits and occurrences of Pb-Zn, Cu, Au, Ag, U, Ba, native sulphur, hydroquartzites, alunites etc. controlled by the fault structures with NW - SE, NNW - SSE, NE - SW strike, as well as the volcanic structures apparatuses.

The ore mineralization in the ore district occurred during late Alpine metallogenic stage but, spatially, genetically and paragenetically, it is related to the fault structures, the structures of the volcanic apparatus and the Tertiary volcanic complexes formations. The volcanic activity, most probably, started by the end of Eocene, while the ore mineralization mainly occurred during Miocene. Numerous occurrences and deposits such as vein type Pb-Zn, stockwork- disseminated Cu, Au, and vein type U mineralization (shear zones) developed as well as a large number of non-metallic minerals such as native sulphur, hydroquarzites, opaline breccia, alunites, jarosite etc.

Based on data available from the investigation and exploration done so far, and the results of our own morphostructural and metallogenic studies, in this ore district three ore fields with several occurrences and deposits of metallic and non-metallic minerals have been distinguished: the Zletovo ore field, Tursko Rudari ore field, and the Pb-Zn and U occurrences in the vicinity of Bajlovce (Fig. 1).

Zletovo ore field (Fig.1 - A) is located in the central part of the Kratovo-Zletovo ore district and according to its size, heterogeneity and spatial distribution of ore mineralization, is the largest and the most important ore field in the ore district. The endogenons ore mineralization is mainly located within the ignimbritic complex of dacite composition, and the Miocene volcanogenic-sedimentary suite (crusscut by dacite-andesite dikes and necks), spatially connected with the fault structures and the volcanic structures.

Stockwork-disseminated copper mineralization and non-metallic raw materials (hydroquarzites, alunites, jarosite etc.) show a direct relation to the volcanic structures (volcanic calderas) first of all the one in Plavica, the Crni Vrv and Bukovik, while the vein ore mineralization of Pb, Zn, u and Cu is mainly related to the fault structures with NW - SE and NE - SW extension. It should be pointed out that the ore mineralization shows certain spatial regularity. The stockwork- disseminated copper and vein Pb-Zn mineralization is prevailing in the central parts, while in the marginal parts or towards the east uranium mineralization is revealed.

Besides the Zletovo deposit, which is in the stage of exploitation, exploratory workings carried out so far revealed numerous deposits and occurrences of metallic and non-metallic minerals. The lead-zinc deposits are Blizanci, Plavica, Zelenigrad, then the occurrences in the vicinity of Jamiste, Zdravci kamen, Slegovo, Prikovci etc. Beside the copper deposit at Plavica and the enargitic veins at Zlatica, copper occurrences have been found in the vicinity of Borovic, Blizanci, Lesnovo; and increased copper contents in the vein lead-zinc mineralization was established in the vicinity of Slegovo - Prikovci. Significan uranium concentrations have been determined in the Zletovksa River deposit, Latisnica and in the vicinity of Dobrevo.

Tursko Rudari ore field (Fig. 1 - B) is situated in the southeastern part of the Kratovo - Zletovo ore district. Unlike Zletovo ore field, it covers a small surface and contains, according to the present rate of exploration, much smaller number of valuable mineral raw materials.

The investigations done so far have determined lead and zinc mineralizations in the area of Belo Brdo, Buneski Dol, Rajcani, Tursko Rudari and Stalkovica, then the copper mineralization near Tursko Rudari, the uranium occurrences near Spancevo, Pogled and Ponikva. More important non-metallic raw materials are the opaline breccias in the Spancevo deposit, the hydroquartzites at Stalkovica and native sulphur occurrences between Pantelej and Banje villages.

The polymetallic mineralization in this ore field is mainly located in strongly hydrothermally altered volcanic tuffs and breccias spatially related to the fault structures with NW - SE (partly NE - SW) extension as well as the volcanic structures. Some of the ore vein structures (in the Stalkovica area) also cut the ignimbrite volcanic complex. It should be pointed out that the large tuffaceous-breciated suite has intensively been intruded by augite-hornblende-biotite and augite-labrador andesites which are the product of the late volcanic activity

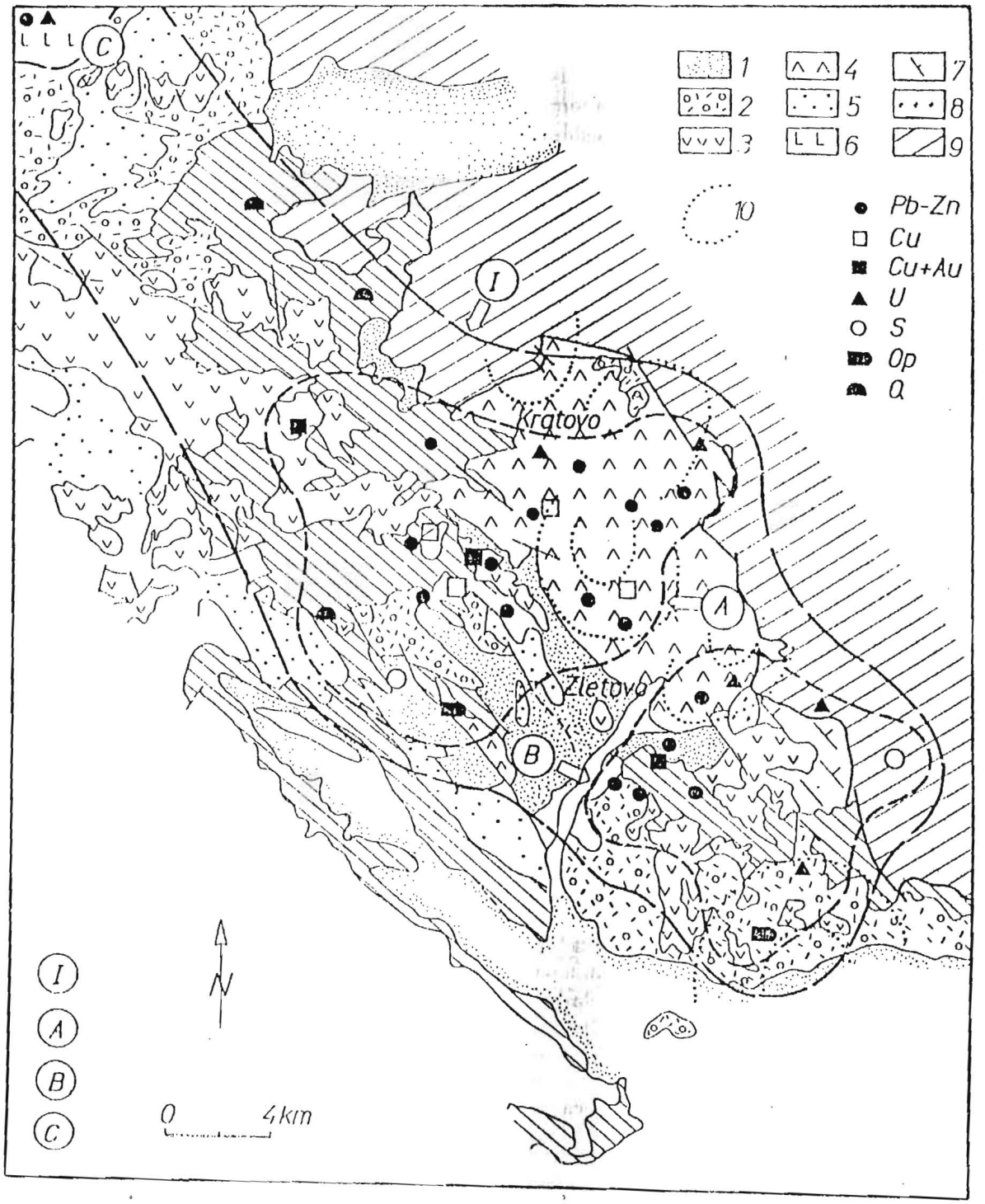

Fig.1. Metallogenetic scheme of the Kratovo-Zletovo ore district

1. Paleogene and neogene sediments, 2. Volcanic breccias, 3. Andesites, 4. Ignimbrites of dacitic composition, 5. Ignimbrites of andesitic composition, 6. Trachytes, 7. Volcano-sedimentary series, 8. Quartz-monzonite porphyry, 9. Schists SMM, 10. Volcanic structures,

I. Contours of the ore district, A. Zlertovo ore field, B. Tursko Rudari Ore Field, C. Bajlovci

stages; their ore mineralization has so far been considered unimportant.

The occurrences of Pb-Zn and U near Bajlovci (Fig. 1 - C) have been distinguished as a separate ore bearing unit which covers the most-northwestern parts of the Kratovo-Zletovo ore district. The ore mineralization is related to highly hydrothermally altered trachytes and trachyandesites, and it is controlled by fault structures with NW - SE, N - S extension as well as their intersections. Besides the lead-zinc ore veins and uranium occurrences, our investigations discovered polymetallic ore structures with low copper contents in the vicinity of Bajlovci with prevailing pyrite in their paragenesis. The ore-bearing area in the vicinity of Bajlovci has been poorly investigated.

3. ORE MINERALIZATION

Investigations carried out so far determined several morphogenetic types of deposits with different mineralization styles the most important being lead-zinc mineralization.

• *Lead-zinc mineralization* - is the only ore that was exploited from the vein type deposits for over half a century. This mineralization style is widespread in the whole ore district. It commonly occurs as ore veins which can be traced from several hundreds meters to 3 km in length, rarely 5 to 10 km (ore vein No.10). In some places the contacts of ore veins with the environment are sharp, but most often they are gradual and accompanied by disseminations and kaolinization and silicifications zones. Lead-zinc mineralization is located in volcanics (most often ignimbrites, dacite-andesites and their tuffs). The Zletovo deposit contains the largest amounts, but several deposts and occurrences can be found in other parts of the district as well. The main metallogenetic features of the mineralization are given in Table 1.

• *Copper Mineralization* - is widespread in the district and most commonly it is connected to the fault-structures, and volcanic apparatus. It occurs in several morphologic types: stockwork-disseminated, vein and in combination. Stockwork-disseminated mineralization with copper and gold is most common. It is located in the structures of the volcanic apparatus or in the zones of intensive hydrothermal alteration of volcanics (the Plavica, Tursko Rudari and Borovic type). Copper contents are low (Table 1), but they are accom-panied by large quantities of valuable metals, first of all gold. The second type is the vein type copper mineralization found in the Zlatica deposit and several other smaller occurences. These enargitic veins with quartz and pyrite were traced for severel hundred meters along strike, and 200 m along dip. Their thickness varies between 0.5 and 2 m. Copper content amounts to 2 % Cu. Ore mineralization is located in strongly hydrothermally altered Tertiary volcanics. Stockwork-disseminated mineralization was also found in the Zlatica deposit. Apart from copper (0.8% Cu), gold pre-sence of up to 1 g/t was determined as well. Mixed type is present in both mineralization styles.

• *Gold mineralization* - is very important and promising. It should be mentioned that exploration carried out so far covered gold within copper mineralization only. Recently, gold investigations in epithermal deposits are more frequent. Nevertheless, the most important gold quantities determined so far in this district are related to stockwork- disseminated (Cu-Au) and vein type copper mineralization.

The epithermal Au mineralization related to the zones of secondary quartzites is particularly important. Amounts of several g/t of gold were determined in individual parts of Plavica, whereas 0.6 g/t Au in the vicinity of Crni Vrv (Table 1). Exploration is still in progress. Secondary quartzites occur as small size lenses and nests within the volcanic structures as well as in the hydrothermally altered volcanics (Fig. 2). They were traced over 100 m in depth, with the tendency of rapid wedging out. Quartzites lying nearer the surface are more abundant in gold.

• *Uranium mineralization* - became very important raw material three decades ago when the main quantities were discovered in the Kratovo-Zletovo district. This mineralization occurs in separate deposits of the Zletovska Reka type, but can often be found in association with lead and zinc (the Zletovo deposit). It occurs as ore veins within the hydrothermally altered and brecciated Tertiary volcanics (most often andesites). Uranium mineralization occurs as impregnations in brecciated zones and as cement round large fragments of brecciated material. It amounts to 1 % U_3O_8 in deposits and less than 0.6 % in determined occurrences (Latisnica, Pogled, Spancevo etc.).

TABLE - 1:General metallogenic features in individual ore deposits in the Kratovo - Zletovo ore District

Deposit	Zletovo (Pb - Zn)	Blizanci (Pb - Zn)	Plavica (Cu -Au)	Borovic (Au - Cu)	Crn Vrv (Au)	Zletovska Reka (U)
Host rock	Ignimbrite	Ignimbrite	Volcanic tuffs/ dacite - andesite	Andesitic tuffs and Aglomerates	Secondary,quartzlatite/Andesite tuffs	Volcanic breccia
Parent igneous rock	Dacite, Andesite	Dacite, Andesite	Andesite, Dacite Quartzlatite	Diorite porphyry dyke/subvolcanic	Andesite dyke/ Subvolcanic	Andesite dyke/ Subvolcanic
Absolute age, m.y.	24 - 28	27	16 - 28	30	25.5	25 - 30
Horizontal projection	3000x500 m	1500x200 m	2500x2000 m	2000x1500 m	3000x2000 m	500x200 m
Vertical extent	>500 m	>200 m	>1000 m	>500 m	150 m	>200 m
Hydrothermal alteration	Sil.Ser.Kl Ch,Lim,Py,Ka	Kl.Ser.Lim.Sil Ch,Py,Mn	Pot.Ser.Biot.Sil Arg.Alu.Ch,E.Kl	Sil.Kl.Ser Ch,Lim,Arg,Alu	Sil.Alu.Kl.Pv Ser,Ch,Arg	Kl.Sil.Ch Ka,Alu,Ser
Association of minerals	Ga.Sp.T.Cv.Pv B.E,Ag,Bi,Mgt	Ga.Sp.Pv Cy,T,Asp,Lim	Cy,Pv.E,Ga.Sp B,Asp,Mgt,Au	Cy.Pv.Au,Mgt Ga,Sp,Lim,B,E	Pv.Au,Q Cy,LIm,Sp,Mgt	Ph,Tor.Ur Py,Ga,Sp,Aut
Constituents of ore	9.10 % Pb 2.29 % Zn 0.09 % Cu 0.04 % Cd 42 ppm Ag Bi,Ba.Fe.Mn.Au.Se	5.50 % Pb 2.61 % Zn 0.01 % Cu 40 ppm Ag Cd,Bi,Mn,Fe	0.16 % Cu 0.319 ppm Au 5.158 ppm Ag 0.137 % Pb 0.188 % Zn 7.16 % FeS2	0.05 % Cu 0.1 - 0.65 ppm Au 0.95 ppm Ag 10 - 15 ppm Mo 0.05 % As 20 ppm Sb	0.1 - 0.6 ppm Au 0.5 ppm Ag 195 ppm As 12 ppm Sb 195 ppb Ag 300 ppm Cu	0.92 % U3O8 Pb, Zn, Cu, Ag, Fe, Mn

ABBREVIATIONS:

Cy - chalcopyrite; Py - pyrite; B - bornite
Ga - galena; Sp - sphalerite; Mgt - magnetite
T - tetrahedrite; E - Enargite, Au - native gold;
Q - qartz

Pot - potassium; Biot - biotitization; Ser - sericitization; Sil - silicification;
Arg - argilization; Ch - chloritization (propylitic); Ka - carbonatization;
Py - pyritization; Lim - Limonization; Lis - listvenitization