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SECTION EXPLORATION AND MINING

RESEARCHES IN THE PHASE OF EXPLOITATION OF THE ORE BODY CUKAR 2 EAST IN FUNCTION OF INCREASING LIFETIME OF THE BUCHIM COPPER MINE, EASTERN MACEDONIA

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ABSTRACT

The Cukar 2 east ore body represents the latest explored ore body within the Mucim Mine with possibilities to enter exploitation stage in near fututre. Calculated ore-bearing coefficient in the Cukar 2 east ore body was 0.40%, meaning that within the ore body boundaries 60% of mass is not mineralized somehow, which is compatible with remaining three ore bodies within the Buchim porphyry copper mine. The calculated value of variation coefficient (V) has shown value of 71.39% that is in the range of 43-100%, which displays that this ore body belongs to the third group of deposits with uneven polymetallic mineralization. An average copper and gold concentrations were determined as 0.206% Cu and 0.165g/t Au, respectively. Minimal economic content (MEC) within the Vršnik ore body, as represent of this kind of mineralization, was determined as 0.211% Cu. In similar manner was calculated the lowest copper boundary (cutoff grade), which have shown value of 0.141% Cu and thus allowing certain decrease of contents in exploited ore. Also, there were calculated so called copper monometal values, which included influence of the present gold and silver in the ore. Calculated copper monometal was set at relatively fair 0.254% Cu that represents solid mainstay for exploitation of copper in these low percentage ores. Calculated ore reserves in this particular ore body were 27 161 276 t of ore with 0.206% Cu and 0.165 g/t Au and increased mine life for additional 5.2 years.

Keywords: Cukar 2 east ore body, copper, exploitation, economic parameters, exploration.

INTRODUCTION

Stages and phases of exploration, and later exploitation within the Bucim Mine started since 1950, where during almost four decades from this mine successfully were exploited copper porphyry ores from an open pit [1], [2], [3] (Figure 1). Of up to now determined 5-6 ore bodies, four of them were exploited and at the moment only Bunardzik ore body is at exploitation stage. Bearing in mind all the data and facts, the managing team of Bucim Mine, at the beginning of 2016, makes an official decision to explore the Cukar 2 east area. With compilation of all data and preparation of the Project for detailed geological exploration was started with final explorations that resulted with additional 1601 m of exploration drilling, followed by proprietary laboratory studies and analyses and completion of geological documentation.

Fig. 1. Location of the Bucim copper mine at the territory of the Republic of Macedonia

At the end of November, 2016 all relevant data about the Cukar 2 east ore body were compiled into an Elaborate with calculation of ore reserves [4]. Conception of continuous exploration in stage of exploitation contributed into definition of Cukar 2 east ore body contours, which should increase timeframe of mine exploitation for additional 4-5 years, Although in it were determined poor copper and gold mineralization of porphyry type it is possible to treat them economically, since the existing infrastructure of Bucim Mine allows input of poor ore with lowest concentration od 0.2 % Cu. Above mentioned features of this ore mineralization gave us an initiative to calculate several important techno-economical parameters, which can define the economic type of this mineralization. Namely, the degree of ore bearing in these types of ore mineralization is variable, but calculation at particular levels and different drill holes gave the more realistic ratio of mineralization within this ore body [4].

GEOLOGICAL FEATURES

Geological composition of the Buchim deposit consists of the Precambrian metamorphic (gneiss, micaschist and amphibolite) and Tertiary rocks. Upper Eocene andesite occur as smaller andesite bodies in form of magmatic breakthrough in gneiss near the Buchim village. They are characterized by light grey to greenish color with porphyry structures and massive textures. Andesite is quite often hydrothermaly altered by silicification, chloritization etc. Pyroclasts are represented by andesite tuff and hroughout the area lie over Miocene and Upper Eocene sediments. Due to pronounced stratification they presumably deposited in some kind of water basin. The major constituents are volcanic ash, plagioclase grains, biotite flakes and sporadicaly occur pyroxene, amphibole and magnetite. The age of the rocks ranges from 27.5 to 24.5 m.y. [3], [5], [6], [7], [8].

Miocene products in the Cukar 2 east deposit area are represented by trachyandesite (near the Shopur, Damjan and Novo Selo villages). They breakthrough the gneiss series and are associated with processes of extensive hydrothermal alteration and mineralization. In color are grey to greenish with massive textures and porphyry structures while their mineral composition is dominated by plagioclase, biotite and sanidine followed by magnetite, titanite, apatite, chalcopyrite, pyrite, chlorite, coisite etc. According to the

chemical and modal composition these rocks were classified as transitions between trachyte and andesite or trachyandesite.

Tertiary volcanic rocks (andesite and trachyandesite), beside various gneiss, are the settings of interest in regards to mineralization in this particular ore body. In general, trachyandesite breakthrough the Precambrian metamorphic complex of gneiss and paragentically is related to the sulfide mineralzations [5], [6]. Petrographic composition mainly classifies them as amphibole-biotite andesite. Andesite and trachyandesite mineral composition consists of feldspar, hornblende and biotite as phenocrystals.

Precambrian products in the area of interest are represented by lenticular-porphyroblast gneiss (southeastern of the Buchim village) that were diffusivelly migmatized. Also, this type of gneiss was determined between villages Bucim and Supurge where gradually became schistose granite. Amphibolite and amphibolite schist occur at all horizonts of highly metamorphozed rocks in form of concordant stripes and lenses od different sizes. They are characterized by dark green color medium to finegrained and sometimes layered with distinctive foliation. They are built of amphibole (hornblende), plagioclase (andezin), followed by epidote-coisite, pyroxene, garnet, titanite, magnetite, pyrite etc. Amphibolite schist are dark green to grey-green in color and composed of hornblende, chlorite and quartz, followed by feldspar, magnetite, titanite, biotite etc. Mica schist and leptinolite occur as separate unit and gradually transform into muscovite gneiss. Pure mica schist occur near the village of Buchim. They are built of quartz, muscovite and biotite with sporadically occurring garnet, feldspar, zircon, titanite, magnetite and pyrite while their color is in general grey with medium to coarse grained structure. Precambrian gneiss in the area occur as biotite gneiss, leucocratic gneiss, two mica gneiss and as muscovite fine stripped gneiss. They are built of feldspar, quartz, biotite, amphibole and muscovite. Gneisses are the most common lithology members and are the most favorable lithology setting for deposition of ore mineralization in the Buchim deposit and Cukar 2 east ore body itself [9], [10]. Within the gneiss serie occur amphibole lenses and amphibole schist. There dominate quartz, K-feldspars, orthoclase, albite (primary and secondary), biotite, epidote etc.

RESEARCHES STAGE

The Cukar 2 east ore body has been defined as result of geological exploration performed in the stage of exploitation within the Bucim Mine and it represents direct contiuation towards east of the Cukar 2 ore body, which had been exploited in 2010. Although, results from prevoius explorations, primarily those before 2012 showed poor copper mineralization with 0.16 to 0.21% Cu, as well as infrastrukture objects displaced in the area (mine gas station, mechanical workshop, objects for workers etc.), managing team of the Bucim Mine in 2012 makes a decision, that area where today stands Cukar 2 east ore body, should be explored with new exploration drill holes along existing exploration net. Exploration took place in 2012 and 2016, when were created conditions for calculation of geological ore reserves within this particular ore body [4]. Here we would like to accent some exploration and economic facts about the Cukar 2 east ore body, which is one from where some of the future production of ore from the mine will come. This ore body was explored in several periods, until 2012 with 37 exploration drill holes totaling 7275 m, in 2012 with 11 exploration drill holes totaling 2100 m and finally in 2016 with 12 exploration drill holes totaling 1601 m or all together 60 drill holes and 10 976 m [4]. As result of these numerous geological explorations of the Cukar 2 east ore body were calculated geological ore reserves of 27 161 276 t with

0.206% Cu and 0.165 g/t Au, which according to present level of technique, technology, market price and active work of the Bucim Mine can be economically produced. These newly calculated geological ore reserves will positively affect the lifetime of the Bucim Mine, especially if we bear at mind that at the moment within the mine is active only Bunardzik ore body.

ORE MINERALIZATIONS

Within the text that will follow we are going to give the major features of the newly explored Cukar 2 east ore body, which is subject of analysis in this paper. The Cukar 2 east ore body is situated in the eastern part of the former Cukar 2 ore body. The mineralization occur in form of veinlets and rarely as impregnations. Vein-veinlets stockwork mineralization is manifested as pyrite-chalcopyrite veinlets, independent chalcopyrite veinlets, quartz-feldspar-pyrite-chalcopyrite veins and deposition. Vein-veinlets mineralization versus impregnations reaches 5:1 ratio. According to the latest detailed geological explorations and determined degree of exploration, density of exploration drill hole along net, it had been indicated complex form of the ore body in form of isometric stockwork-impregnated form, which changes its contours at depth (Figure 2).

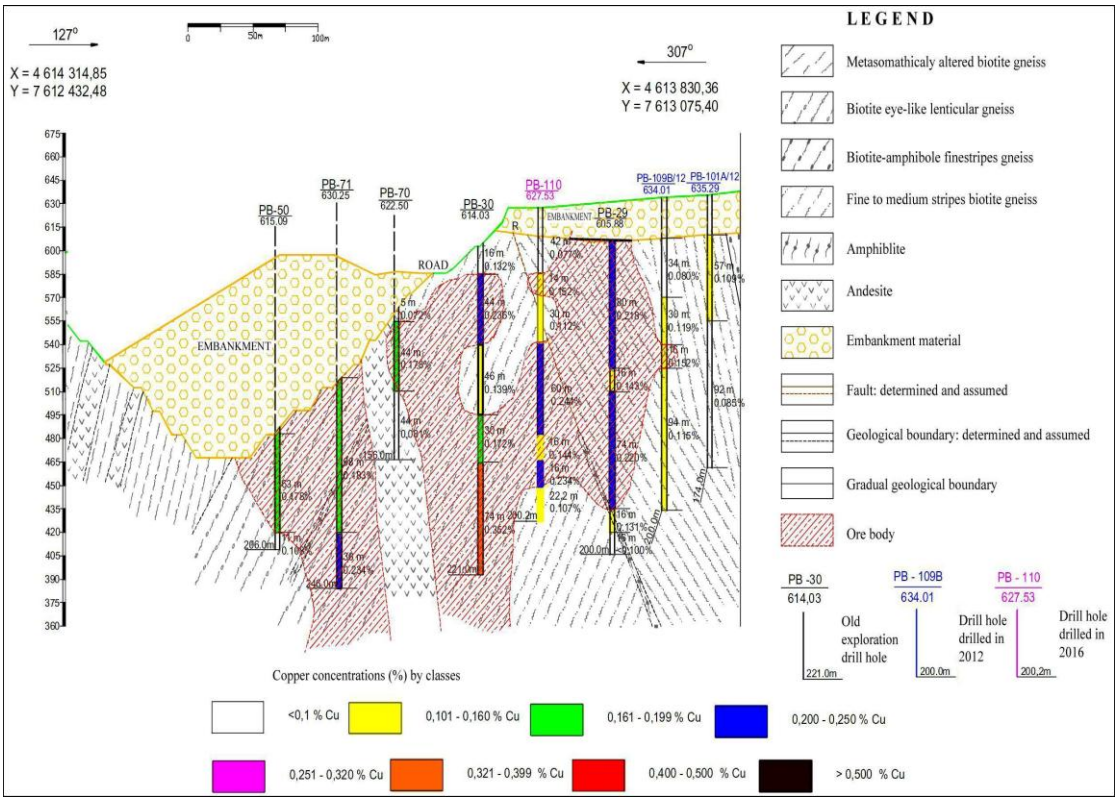

Fig. 2. Geological cross section of the Cukar 2 east ore body within the Buchim Cu-deposit [4]

In regards to mineralization the following minerals has been confirmed there: pyrite, chalcocite, chalcopyrite, pyrrhotite, magnetite, Fe-hydroxide, covellite, ilmenite, sphalerite, galena, molybdenite, enargite, anglesite, malachite, cassiterite, bornite etc.

TECHNO-ECONOMIC PARAMETERS

Within this chapter we are going to display the major parameters of the techno-economic evaluation of the Cukar 2 east ore body situated in the Buchim copper mine, which directly are pointing out to a possibility of productive exploitation of copper ore from this particular ore body and possibility to create economic benefit or simply said profit. So, here in more details are given results from calculations of ore-bearing coefficient, variation coefficient, average concentrations of major ore metals (Cu, Au), minimal economic concentration, cutoff grade, calculation of mine life as a function of calculated ore reserves.

Ore-bearing coefficient.- The ore-bearing coefficient defines the ratio between the total mineralized area within the ore body and certain poor (waste) zones (content below the limit of 0.15% Cu), within that same ore body. In the Vrshnik ore body from the 18 exploration cross sections with 60 drill holes and 7985 m of mineralized area, 3172 m were mineralized above 0.15% Cu while the 4820 m displayed mineralization below the limit of 0.15% Cu, but however significantly over the Clark values. Using the formula given below [11], we have managed to calculate aforementioned coefficient.

$$K_r = \frac{m_1}{m_2} = \frac{3172}{7985} = 0.40$$

Kr - Ore-bearing coefficient
m_1- Productive interval (mineralized area >0.15% Cu)
m_2 - Total mineralized interval

This gave us an opportunity to calculate the ore-bearing coefficient of 0.40, which points out that within the defined ore body there are 60% of mass below the accepted minimal economic concentration of 0.15% Cu. Additionally we would like to stress out that the ore-bearing coefficients throughout all drill holes ranged from 0.05 up to 1.0 while along the exploration cross sections those ranges were slightly narrower, 0.26-0.53.

Variation coefficient.- This coefficient defines spatial distribution of useful mineral components in the the deposit or more precisely how evenly mineralization is represented in the deposit (ore body). In the Vrshnik body's case there were drilled 60 exploration drill holes of which 23 drill holes defined the narrower area of the Cuakr 2 east ore body. In those 23 drill holes were sampled 816 samples, which have defined an average contents of Cu, Au, Ag and Fe_3O_4. The basic parameters for calculation of variation coeficient in the Cukar 2 east ore body were selected from 23 the most representative drill holes totaling 816 m [4]. The value of 71.39% for the variation coefficient is within the range of 32-92%, which points out to an irregular mineralization representative for most of the hydrothermal copper and polymetallic mineralizations.

An average concentration of useful component(s) .- An average concentation of useful component represents the average presence of one or more components within an ore body. By the basic method of calculation of ore reserves within the Cukar 2 east ore body (level blocks) it was determined that for calculated B and C1 category of reserves the average values of useful components are 0.206% Cu and 0.165 g/t Au.

Calculating the Minimal Economic Concentration (MEC). – This calculation should provide a clear answer to the question, does the explored deposit or ore body

(represented by calculated reserves within) can fulfill the economic requirements for viable exploitation of that ore body. Aforementioned calculation should display, does the exploitation will cover all the production costs and in the same time to achieve adequate profit, equivalent to the required cost effective coefficient. Bearing in mind that here we were working only with one small part of the Buchim deposits, we used Gudalin's formula [11] where have been considered the following parameters: exploitation costs, utilization of the mineral resource, price of the final product or more precisely the final ore product (copper and gold) [4]. According to all analytical and statistical data, calculated MEC for this ore body is as follows:

MEC = 0.211 % Cu

Calculated minimal economic concentration displays that for a cost effective production the MEC value should not be lower than 0.211% Cu.

Calculation of monometal.- Ore reserves calculation of the Cukar 2 east ore body have shown that it is natural product that contains in average 0.206% Cu and associated element 0.161g/t Au. Comparing those values of useful components with the necessary MEC (0.211% Cu) we may conclude that the ore body have contents lower than the minimal one. In those cases we trying to calculate all present useful components to one monometal (in this case copper). That calculation was performed using transformation factor (*f*) for associated components (Au) on the basis of Cu expressed as monometal [4], below:

$$Cu_{monometal} = 0.254\%$$

The calculation above have shown that useful components calculated to the Cu monometal is 0.254% Cu, which is higher than the needed one calculated with MEC (0.211% Cu) and in that direction the ore reserves can be considered as economically viable itself.

Cutoff grade.- This grade defined as the level of mineral in an ore below which it is not economically feasible to mine (GS) was calculated after intensive analysis of several parameters such are: dilution coefficient of ore during excavation (L_e=3%), efficiency of usability during enrichment (L_o=88%), efficiency of usability during metallurgical processing (L_m=95%), cost for enrichment of 1t ore (S_o=4.70 US$/t), transport costs for 1 t of ore concentrate (S_t=22 US$/t), costs for metallurgical processing per unit of final product (S_m=1000 US$/t), market price of copper at the moment of calculation (C_o=5200 US$/t), costs for excavation of 1t of ore and copper metal content in ore concentrate (g=21%). In that manner we have calculated the cutoff grade as follows:

$$GS = \frac{100 \cdot So}{Le \cdot Lo \cdot Lm \cdot \left(Co - Sm - \frac{100St}{gLm} \right)} = \frac{100 \cdot 6.14}{0.97 \cdot 0.88 \cdot 0.95 \left(5200 - 1000 - \frac{100 \cdot 22}{21 \cdot 0.95} \right)} =$$

$$= \frac{470}{0.97 \cdot 0.88 \cdot 0.95 \left(4200 - \frac{2200}{19.95} \right)} = 0.141\%$$

GS= 0.141% Cu

The calculated cutoff grade takes only copper in consideration although we have gold as valuable component in the Cukar 2 east's ore. Bearing in mind all the above calculated parameters we have calculated the ore reserves within the Vrshnik ore body and corresponding concentrations of certain metals in them (Table 1).

Table 1. Calculation of ore reserves in the Cukar 2 east ore body

Parameters		Category		
		B	**C_1**	**B + C_1**
Commodity	**unit**	13635916	13525358	27161276
Cu	%	0.204	0.208	0.206
Au	g/t	0.177	0.155	0.165
Cu	t	27871.2	28148.4	56009.6
Au	kg	2408.7	2096.7	4481.5

From the total of calculated ore reserves in the Cukar 2 east ore body in an ammount of 27 161 276 t (B+C_1 category) with an average content of 0.206% Cu and 0.165 g/t Au and annual mine production of 4 000 000 t of ore, we were able to calculate the timeframe of total exploitation of this particular ore body:

$$V_E = \frac{Q \cdot K_r}{G_K} = \frac{55952 \cdot 0.77}{8240} = 5.2 \quad years$$

V_E -period of exploitation
Q – ammount of metal in the deposit (t)
K_r – coefficient of utilization of geological ore reserves (77%)
G_k- annual metal production capacity (t)

As can be seen the Cukar 2 east ore body will extend Buchim mine's life for additional 5.2 years, which all together with the calculation that only copper in this ore body is worth 139 400 000 US/$, gives us the real value of the results of the exploration this ore body.

CONCLUSION

The Cukar 2 east ore body represent typical example of dfined ore body within the Bucim Mine, where exploration stage took place during the exploitation stage of the mine. Defined porhyry mineralization in the Cukar 2 east ore body represents direct continuation of already exploited Cukar 2 ore body. Calculated ore reserves of 27161276 t in this ore body occupy infrastructural area within the mine where have been located mechanical workshop, mine gas station, several annex buildings etc. With exploitation of this particular ore body that will follow in the fututre all those infrastructural objects will be dislocated. It is expected that around 70% of calculated geological ore reserves within the Cukar 2 east ore body will be exploited with future open pit explitation. These calculations increase the lifetime of the mine for additional 5 years. Defined average concentration of mineralization is 0.206% Cu and 0.165 g/t Au and it belongs to a category of poor copper mineralizations of porphyry type, but however the existing infrastructure of the Bucim Mine allows exploitation of such type of ore.

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