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# VALUABLE MINOR COMPONENTS IN THE COMPOSITION OF PORPHYRY COPPER DEPOSITS

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ABSTRACT
Porphyry copper deposits in Bulgaria are the main source for copper production. There are valuable minor components in the mined ores such as: gold, silver, molybdenum, platinum, palladium, selenium, tellurium, bismuth, cobalt, nickel. The subject of the present paper is to study their distribution and form of occurrence. The contents of minor elements in the mineral ore types in porphyry copper deposits are different. Most of these elements form their own minerals. Their main bearers are sulphide minerals which favors the concentration of these elements in the final product - the flotation concentrate. The correlation coefficients of the distribution of minor elements as compared to copper are: 0,77 for gold; 0,71 for silver; 0,48 for palladium; 0,12 for platinum; 0,54 for tellurium; 0,94 for bismuth and 0,82 for selenium. At present, in the process of production and processing of copper ores from these deposits, the attention is focused on the content of copper and gold. Our studies show, that the rest of minor components are a great potential for increasing the industrial value of the deposits and the competitive power of the mining product. The results obtained can be used for important technological solutions in the complex utilization of the ores.

## INTRODUCTION

Porphyry copper deposits are the main source for copper production. Low contents of this useful component - less than 0,50 % are typical for them. They contain a number of minor components that exceed many times the price of copper. In spite of the low copper contents, porphyry copper deposits in the world are profitable due to the fact that a considerable amount of gold, silver, molybdenum and other useful components is being produced from them.

The object of the present paper are the minor components in porphyry copper deposits in Bulgaria, their distribution in mineral type of ores according to B. Bogdanov (1987) and form of occurrence. Scattered data have been published on this problem in the literature (Dimitrov, 1974-1975; Bogdanov et.al.,2000; Dragov et.al.,1996; Strashimirov et.al.,1994), but they do not allow to make a complete appraisal of the mineral deposits.

### Methods

The samples were collected from ore that was produced during the last year from the working open pit mines “Elatzite” and “Assarel”. Investigations at the level of mineral aggregates and minerals have been carried out. In “Elatzite” deposit, samples from the main mineral ore types have been analyzed: chalcopyrite - pyrite - molybdenum and from magnetite - bornite - chalcopyrite with vein-impregnated character of the aggregates and compact bornite mineralizations locally met in fault zones (Tokmakchieva, 1999). In “Assarel” deposit, samples from the chacocite - covellite mineral type have been analysed. Chemical and microbeam analyses have been carried out at the chemical Laboratory of the Mining and Geology University, Scientific and Research Center “Eurotest” and Hamburg University, Institute of Minerology and Petrography. Most of the analyses have been made with the help of Prof. M. Tarkian from the Hamburg University, Department of mineralogy and petrography for which I personally thank him.

PGE and Au have been analysed in Madington Laboratory, Australia. The sensitivity limit for Pd, Pt and Au is 1 ppb (1 mg/t). Most of the Ag, Te, Bi, Se, Mo, Ni, Co analyses have been carried out at the Ontario Laboratory, Canada by ICP method. The sensitivity limit is: 0,2 mg/t (for Te, Bi, Se); 0,5 g/t (for Ag); 1 g/t (for Ni, Co); 2 g/t for Mo. Part of the microbeam analyses have been made by Cameca Camebax Microbeam wavelength - dispersive electron microprobe at the Department of Mineralogy and Petrography at Hamburg University. The operational regime is 20 kV and 21-22 nA at used standards: native elements for gold, silver, palladium, bismuth, tellurium; pyrite for iron; chalcopyrite for copper and sulphur; synthetic PdSb.

Minor elements can be ranged according to their importance as follows: gold, silver, molybdenum, platinum, selenium, tellurium, bismuth, cobalt, nickel. At present, mining companies control only copper, gold and sulphur. The aim of the present study is to draw attention to the rest of the minor components. Their complex processing and utilization increases the value of the deposits and the efficiency of mining.

### Results

The chemical content of the produced porphyry copper ores is different. High content of $SiO_2$ (between 59,16 and 61,98 %), of $Al_2O_3$ (between 17,18 and 18,45 %) is typical for “Elatzite” deposit. The content of $K_2O$ (between 4,12 and 5,62 %) is higher than the content of $Na_2O$ (between 3,87 and 4,29 %). A series of rare elements was established in the ore: V, W, Sr, Rb (between 100 and 700 g/t), Ce, Ga, La, Y, Zn, Zr (between 10 and 85 g/t) Cr, Cs, Pb, Th, U, Yb, Ta (between 0,5 and 4 g/t). In "Assarel" deposit, the $SiO_2$ content is between 60,97 and 78,65 %, $Al_2O_3$ - between 6,27 and 24,31 %, $K_2O$ - between 0,14 and 5,11 % and $Na_2O$ - between 0,18 and 3,95 %. The contents of these rare elements are 10 times smaller in comparison with those of "Elatzite" deposit. In "Assarel" deposit, the main ore minerals are: chalcocite, covellite, secondary bornite and djurleite (suppergenic) which replace the primary chalcopyrite and pyrite in the form of pseudomorphoses. Other rarely met hydrothermal minerals are: bravoite, thentite, tetrahedrite, molybdenite - 2H, siegenite, sphalerite, galena, arsenopyrite, gold, silver, electrum (Tokmakchieva, 1994). The produced ores from "Elatzite" deposit contain the following main ore minerals: chalcopyrite, pyrite (nickel pyrite, cobalt pyrite), molybdenum, bornite, and in smaller amount tennantite, tetrahedrite, pyrrhotite - 1C, siegenite, arsenopyrite, marcasite, sphalerite, galena, bournonite, electrum, platinum, hematite, linnaeite, carrollite, clausthalite, gold, hessite, naumannite, merenskyite (Tokmakchieva, 1999). According to the concentration of the main ore minerals, two mineral subtypes can be divided: chalcopyrite - pyrite - molybdenum and magnetite - bornite - chalcopyrite. The chalcopyrite - pyrite - molybdenum mineral ore type is widespread on the surface of the ore body while the magnetite - bornite - chalcopyrite mineral ore type is concentrated mainly in its southwestern part. The distribution of the minor components will be discussed on the background of these general data

In "Elatzite" deposit, the content of ***gold*** is 0,14 g/t. Its contents in the chalcopyrite - pyrite - molybdenum mineral ore type are from 0,2 to 0,8 g/t and for magnetite - bornite - chalcopyrite mineral type from 0,7 to 1,5 g/t (Table 1). In the concentrate from the processing plant, the contents of gold are between 10 and 14 g/t (at 25 % Cu). The coefficient of correlation of gold to that of copper is 0,77. Gold was established by microbeam analyses in the content of chalcopyrite, pyrite and bornite (Table 2). It was observed in its own mineral form: gold (Au = 90,45 g/t and Ag = 9,49 g/t) and electrum (Au = 57,7 g/t and Ag = 41,8 g/t). Grain sizes are from 1 to 10 microns and rarely 50 microns. In the ore produced from "Assarel" deposit, gold content is 0,06 g/t while in the concentrate it is 2,5 g/t (at 20 % Cu). By microbeam analyses it can established only in chalcopyrite (0,5 g/t). Chalcopyrite and bornite concentration in the vein - impregnated ores determines the variations in gold contents. The highest contents of gold 50 and 120 g/t are in compact bornite mineralizations having local distribution (Table 1) and being insignificant part of the ore mass.

Millions of tons of ore are being produced and processed from porphyry copper deposits. Although gold content is low, these deposits are an important source for its production. Gold content should be calculated at estimating the industrial value of perspective porphyry copper deposits. These recommendations concern other deposits of different genetic type that are not being discussed in this paper, such as: "Praveshka Lukavitza" - 0,10 g/t Au; "Karlievo" - 0,06 g/t Au; "Gorna Kamenitza" - 0,15 g/t Au; "Petelevo" - 1,31 g/t (M. Tokmakchieva, 1994).

***Silver*** is another minor component. Its content in the chalcopyrite - pyrite - molybdenum mineral type from "Elatzite" deposit varies from 1 to 12 g/t in magnetite - bornite - chalcopyrite - from 1 to 5 g/t and in compact bornite mineralizations - from 10 to 100 g/t (Table 1). The coefficient of correlation compared to Cu is 0,71. Its distribution in the ore body has a coefficient of accumulation 40 reaching 1 in the outer zones. Its quantitative distribution directly depends on the chalcopyrite and bornite distribution reaching high contents (Table 2). In compact bornite mineralizations bohdanowiczite, naumannite (Ag = 73,93 %; Fe = 0,53 %, S = 22,83 %), hessite (Ag = 63,61 %; Cu = 1,25 %; Fe = 0,12 %; Sb = 0,23 %; Te = 36,71 %) can be found.

Table 1 Contents of valuable minor components in the composition of Bulgarian porphyry copper deposits - mineral types: 1 - chalcopyrite-pyrite-molybdenite (98 analyses); 2 - magnetite-bornite-chalcopyrite (21 analyses); 3 - compact bornite mineralizations (18 analyses); chalcocite (35 analyses)

| Element | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Au | from 0,2 g/t to 0,8 g/t | from 0,7 g/t to 1,5 g/t | from 10 g/t to 12 g/t | from 0,06 g/t to 1 g/t |
| Ag | from 1 g/t to 12 g/t | from 1 g/t to 5 g/t | from 10 g/t to 100 g/t | from 5 g/t to 20 g/t |
| Mo | from 50 g/t to 760 g/t | 2 g/t | 2 g/t | под 10 g/t |
| Pt | from 1 mg/t to 16 mg/t | from 11 mg/t to 55 mg/t | 28 mg/t | - |
| Pd | from 6 mg/t to 27 mg/t | from 5 mg/t to 87 mg/t | 73 mg/t | - |
| Se | from 20 g/t to 410 g/t | from 250 g/t to 600 g/t | 800 g/t | from 3 g/t to 40 g/t |
| Te | from traces to 0,8 g/t | from 20 g/t to 106 g/t | 380 g/t | from 0,5 g/t to 20 g/t |
| Bi | from traces to 1,5 g/t | from 79 g/t to 291 g/t | - | 0,9 g/t |
| Co | from 21 g/t to 90 g/t | 37-120 g/t | 120 g/t | - |
| Ni | from 10 g/t to 48 g/t | 47-100 g/t | 260 g/t | - |

Table 2. Microprobe analyses of: 1 - chalcopyrite (15 analyses); 2 - pyrite (12 analyses); 3 - bornite (9 analyses) from "Elatzite" deposit; 4 - chalcocite (8 analyses) and 5 - covellite (12 analyses) from "Assarel" deposit

| Elem % | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Cu | 33,33 | - | 60,68 | 79,83 | 66,39 |
| Fe | 30,69 | 46,60 | 11,66 | - | - |
| Au | 0,09 | 0,03 | 0,09 | - | - |
| Ag | 0,003 | 0,001 | 0,11 | 0,001 | 0,001 |
| Pt | 0,0003 | - | - | - | - |
| Pd | 0,0001 | - | - | - | - |
| Co | 1,61 | 0,10 | - | - | - |
| Ni | 0,22 | 0,01 | - | - | - |
| Bi | 0,001 | 0,001 | - | - | 0,0001 |
| Se | 0,001 | 0,001 | 0,001 | 0,0001 | 0,0001 |
| Te | 0,001 | 0,001 | 0,001 | 0,0001 | 0,0001 |
| S | 33,61 | 53,28 | 26,85 | 19,85 | 33,45 |
| Total sum | 99,56 | 100,92 | 99,39 | 99,68 | 99,84 |

The dimensions of the inclusions are between 10 and 60 microns. The content of silver in the processed concentrate is 34 g/t. Djurleite is one of the main ore minerals in the mineral content of "Assarel" deposit. It is mixed with chalcocite and covellite and is the main silver-bearer. Its concentrations depend directly on the quantity of accumulation of this hypergenic mineral. The coefficient of silver accumulation in the ore body is 100 and in the outer zones and aureoles – from

0 to 1. The average silver contents in the produced chalcocite – covellite mineral ore type is 10 g/t and between 30 and 70 g/t in the concentrate from the processing plant.

Silver has not been calculated as an element in the balanced ores of porphyry copper deposits in spite of being a typical element for such genetic type deposits.

Irrespective of the low silver content as compared to lead-zinc and stratiform deposits, porphyry copper deposits can be an important source for production of this precious metal if we take into account the large amounts of mined ore (millions of tons).

***Molybdenum*** is a minor component of industrial importance for porphyry copper deposits. According to P. Vassilev (2001), “Elatzite” is a molybdenum – bearing deposit, while B. Bogdanov (1987) considers it a copper – molybdenum – porphyry type. The average molybdenum content in the balanced ores of “Elatzite” deposit is 0,005%. Molybdenum content in outbalanced reserves of other deposits of this type is: "Karlievo – 0,005%, “Studenetz” – 0,005%, “Gorna Kamenitza” – 0,004% (P. Vassilev, 2001). For “Elatzite” deposit, molybdenum is a mineral of secondary importance. That is why the concentration coefficients of molybdenum in the ore body compared to its contents in the aureoles are between 80 and 90. Molybdenum is from 50 to 760 g/t in the chalcopyrite – pyrite – molybdenum mineral ore type and about 1 g/t in magnetite – in the bornite – chalcopyrite type (Table 1). Its content in the processed concentrate is 1300 g/t. Apart from molybdenum, molybdenite is a bearer of another valuable component – rhenium (up to 200 g/t in this mineral). The prices of both elements are several times higher than those of the metals produced from the deposit. Their calculation and utilization will contribute to a more efficient mining activity.

Molybdenum is not a typical element for “Assarel” deposit as well for the porphyry copper – allunite subtype (B. Bogdonov, 1987). The coefficient of accumulation in the ore body, compared to its concentrations in the aureoles, is 30. Molybdenum content in the chalcocite – covellite mineral ore type is less than 10 g/t.

Until recently ***platinum and palladium*** have not been considered as typical elements of this genetic type of deposits. Mineralogical studies in the last few years proved that considerable quantities of these valuable minor components can be found in the content of “Elatzite” deposit. The content of platinum in the chalcopyrite – molybdenum mineral ore type is between 1 and 16 mg/t and that of palladium – between 6 and 27,5 mg/t. In the magnetite – bornite – chalcopyrite mineral type, the content of platinum is between 5 and 87,5 g/t. In the compact bornite mineralizations, the quantity of platinum is 28 mg/t and that of palladium – 73,3 mg/t. (Table 1). Platinum and palladium are related mainly to chalcopyrite (Table 2). Inclusions of platinum, merenskyite (Pd = 17,66%; Pt = 13,73%; Cu = 1,82%; Ag = 1,40%; Te = 60,77%; Bi = 3,33%; Sb = 0,37%), palladium–arsenite, palladium, ramelsbergite (M. Tokmakchieva, 1999) can be found in chalcopyrite. Correlation coefficients of its distribution in the mineralization, as compared to copper, are 0,48 for palladium and 0,12 for platinum, respectively. Platinum 6,1 mg/t and palladium – 28,9 mg/t have been determined in the flotation concentrate. Earlier studies of M. Tarkian et al. (1999) show that platinum quantities in the flotation concentrate of “Elatzite” deposit are 0,23 g/t for 1996 and 0,15 g/t for 1998, and palladium quantities – 1,0 and 0,74 g/t, respectively. According to the same author, these values are among the highest as compared to other porphyry copper deposits in the world that produce both precious metals. The prices of both components are twice higher than those of gold and many times higher than those of copper. For the time being they have not been considered in the balanced reserves and in the content of the final product. Their utilization will contribute to its higher competitive power.

***Selenium and tellurium*** are typical minor components in porphyry copper deposits. According to P.Vassilev (2001) balanced reserves have been calculated for “Elatzite” deposit containing 1463,5 tons of selenium metal in balanced and 243,2 tones selenium metal at average content 6 g/t in outbalanced reserves. Our studies prove that selenium from 20 to 410 g/t and tellurium to 0,8 g/t can be found in the chalcopyrite – pyrite – molybdenum mineral ore type. Selenium between 250 and 600 g/t and tellurium between 20 and 106 g/t can be found in the magnetite – bornite – chalcopyrite mineral ore type (Table 1). Correlation coefficients of distribution compared to copper are 0,82 for selenium and 0,54 for tellurium. The contents of selenium reach 800 g/t and those of tellurium – 380 g/t in the composition of compact bornite mineralizations. Selenium is found by in own mineral form in aumannite, bohdanowiczite, eucyrite, clausthalite (Pb = 77,45%; S = 5,07%; Se = 17,48%) and for tellurium – tellurium, weissite, hessite, merenskyite (Tokmakchieva, 1999). For “Assarel” deposit, selenium contents are from 3 to 40 g/t and those of tellurium – from 0,5 to 20 g/t. Selenium and tellurium are found in the composition of sulphide minerals as pyrite, bornite, taenite, tetrahedrite, sphalerite, molybdenite, chalcocite, covellite with trace contents to 100 g/t and 2400 g/t for chalcopyrite (Tokmakchieva, 1994). R. Petrunov et al. (1991) described goldfieldite in “Assarel” deposit. The distribution of the main ore minerals in “Elatzite” deposit (pyrite and chalcopyrite) and in “Assarel” (chalcopyrite, pyrite, chalcocite and covellite) controls the selenium and tellurium concentrations in the produced ore. These minor components are concentrated in the flotation concentrates.

***Bismuth*** occurs in higher concentrations in the magnetite – bornite – chalcopyrite mineral ore type in “Elatzite” deposit in the limits 79 to 291 g/t. For the chalcopyrite – pyrite – molybdenum mineral type the contents are up to 1,5 g/t. About 20 g/t bismuth is contained in the concentrate. For “Assarel” deposit bismuth contents are up to 0,9 g/t (Table 1). Bismuth is related to the main sulphide minerals: in chalcopyrite – 0,0001% (“Assarel” deposit) and 0,001 % (“Elatzite” deposit); in pyrite – 0,0001 %; in tetrahedrite – from 1,34 to 2,03 %; in covellite and chalcocite – 0,0001% (Table 2). The variations of its content in the ore depends on the concentration of the sulphide ore minerals. For this reason the bismuth coefficient compared to copper is high – 0,94. There are inclusions of aikinite, wittichenite, merenskyite, bismuth, bohdanowiczite that are typical for late bornite mineralizations in chalcopyrite.

***Cobalt and nickel*** are typical elements for the porphyry copper deposit of “Elatzite”. Their contents in the chalcopyrite – pyrite – molybdenum mineral ore type are from 21 to 90 g/t for cobalt and from 10 to 48 g/t for nickel, and in the magnetite – bornite – chalcopyrite type – from 37 to 120 g/t for cobalt and from 47 to 100 g/t for nickel (Table 1). Cobalt contents in concentrates are 94 g/t and nickel contents – 151 g/t. In the ore body the concentration coefficients of cobalt reach 50 and those of nickel – 20. Towards the outer zones in the aureoles these values decrease from 1 to 3 (Tokmakchieva, 1994). According to Strashimirov (1982) and P. Dragov (1972), the higher concentrations of cobalt and nickel are typical for porphyry copper deposits in the middle part of the Balkan Mountain. Cobalt and nickel occur in chalcopyrite and pyrite (Table 2). In separate microbeam analyses, cobalt and nickel are found in tetrahedrite, tennantite, bornite and sphalerite. In compact bornite mineralizations, in which the content of cobalt reaches 120 g/t and that of nickel – 260 g/t, inclusions of millerite, rammelsbergite, cobaltite, linnaeite can be observed (Ni = 9,53%; Fe = 0,73%; Co = 32,62%; Cu = 15,40%; S = 41,85%), carrollite, siegenite (Ni = 41,14%; Fe = 1,76%; Co = 15,13%; Cu = 0,38%; S = 41,82%) cobalt pyrite (Fe = 29,73%; Cu = 0,32%; Co = 14,90%; Ni = 0,11%; S = 53,65%) and nickel pyrite (Fe = 38,43%; Cu = 0,05%; Co = 0,09; Ni = 6,72%; S = 53,96%).

Other ***rare elements*** with higher contents can be also found in the mined ores: germanium – up to 0,6 g/t; mercury – from 1 to 8 g/t (in bornite mineralizations); antimonium – 0,6 to 5 g/t (270 g/t in concentrates). Arsenic is in the limits of 1,3 to 3 g/t in ores and 30 g/t in concentrate. The contents of lead in the flotation concentrate are 204 g/t and those of zinc – 128 g/t. We are not concerned with them in the present paper.

## CONCLUSION

Bulgarian porphyry copper deposits are a source not only of copper and sulphur but also of a series of valuable components such as gold, silver, molybdenum, rhenium, platinum, palladium, selenium, tellurium, cobalt, nickel and bismuth.

The average contents of gold, silver, platinum and palladium in sulphides (Table 3) and in concentrates are among the highest as compared to other porphyry copper deposits in the world. Table 3 and 4 prove that fact giving results of other researchers. Unpublished data (Tarkian et al.) show that in the produced ore from “Elatzite” deposit gold is 14,2 g/t, silver – 72 g/t, platinum – 0,16 g/t and palladium – 0,55 g/t. Minor elements can be found in the main sulphide minerals due to which their contents are extremely high in the ores with concentration of sulphides. According to published data by M. Tarkian and B. Stribrny (1999) they are:
for “Elatzite” deposit: Au = 27000 mg\t, Pd = 1900 mg\t; Pt = 72 mg\t; Cu = 25.9 %; Au\Pd = 14; Pd\Pt = 26,4; Silicate content (vol %) = 20
for “Medet” deposit: Au = 5600 mg\t; Pd = 160 mg\t; Pt = 8 mg\t; Cu = 14,9 %; Au\Pd = 35; Pd\Pt = 20; Silicate content (vol%) = 40
for “Tzar Assen” deposit: Au = 130 mg\t; Pd = 8 mg\t; Cu = 15.9 %; Au\Pd = 16; Silicate content (vol%) = 20
for “Prohorovo” deposit: Au = 200 mg\t; Cu = 4,3 %; Silicate content (vol%) = 25.

Table 3. Average contents of gold, silver, platinum and palladium in sulphide concentrates from Bulgarian and some foreign porphyry copper deposits.

| Name | Average contents of: | | | |
|---|---|---|---|---|
| **country** | gold | silver | platinum | palladium |
| Deposit | | | | |
| **Bulgaria** | | | | |
| *Elatzite | 27000 mg\t | – | 72 mg\t | 1900 mg\t |
| Elatzite | 14,2 g\t | 72 g\t | 0,16 g\t | 0,55 g\t |
| *Assarel | 8 g\t | – | 12 mg\t | 160 mg\t |
| Assarel | 2,5g\t | 70 g\t | – | – |
| **Greece** | | | | |
| *Scouri | 7300 mg\t | – | 8 mg\t | 160 mg\t |
| **Serbia** | | | | |
| *Midanpeck | 7000 mg\t | – | 24 mg\t | 240 mg\t |
| **The Phillipins** | | | | |
| *Santo Thomas II | 40 g\t | 45 g\t | 1,85 mg\t | 2,67 mg\t |
| *Biga | 2350 mg\t | – | 8 mg\t | 56 mg\t |
| **USA** | | | | |
| *Bute | 310 mg\t | – | – | – |
| *Bigman | 1350 mg\t | – | – | – |
| **Armenia** | | | | |
| *Kadjaran | 3400 mg\t | – | 84 mg\t | 24 mg\t |
| **Kazahstan** | | | | |
| *Sayak | 25000 mg\t | – | – | – |
| **Canada** | | | | |
| *Gibraltar | 280 mg\t | – | – | – |
| **Uzbekistan** | | | | |
| *Almalik | 9800 mg\t | – | – | 20 mg\t |
| Notes: * according to data of M. Tarkian and B. Stribrny (1999) (–) no data | | | | |

Table 4. Average contents of gold, silver, platinum and palladium in concentrates from Bulgarian and some foreign porphyry copper deposits

| Name | Average contents of: | | | |
|---|---|---|---|---|
| **Country** | gold | silver | platinum | palladium |
| Deposit | | | | |
| **Bulgaria** | | | | |
| *Elatzite | 7600 mg\t | – | 170 mg\t | 760 mg\t |
| Elatzite | 14 g\t | 34 g\t | 155 mg\t | 740 mg\t |
| *Assarel | 4800mg\t | – | 14 mg\t | 54 mg\t |
| Assarel | 2,5 g\t | 70 g\t | 10 mg\t | 50 mg\t |
| **Serbia** | | | | |
| *Bor | 1700 mg\t | – | 19 mg\t | 40 mg\t |
| *Midanpeck | 7,8 g\t | – | 0,03 g\t | 0,27 g\t |
| **Malaysia** | | | | |
| *Mamut | 18,7 g\t | – | 0,57g\t | 1,7 g\t |
| **Papua** | | | | |
| *Oktedi | 17 g\t | – | 0,02 g\t | 0,62 g\t |
| **Chile** | | | | |
| *Chukvikamata | 470 mg\t | – | – | 36 mg\t |
| *El Salvador | 1250 mg\t | – | 8 mg\t | 16 mg\t |
| **Argentina** | | | | |
| *Elumbrella | 31000 mg\t | – | 8 mg\t | 35 mg\t |
| **Iran** | | | | |
| *Sar cheshme | 840 mg\t | – | – | 24 mg\t |
| **Indonesia** | | | | |
| *Gresbig | 1800 mg\t | – | 15 mg\t | 58 mg\t |
| Notes: * according to data of M. Tarkian and B. Stribrny (1999) (–) no data | | | | |

Similar results have been published by the present author about bornite compact mineralizations (Tokmakchieva, 1999). The data published by R. Petrunov et al. (1992) about a mineralization referred to as magnetite – bornite – chalcopyrite mineral type correspond to our results.

Flotation concentrates from "Elatzite" and "Assarel" deposits contain these valuable minor components. The results presented in this paper correspond to published data by M. Tarkian et al. (1999) as follows:
"Elatzite" deposit: Au = 7600 mg\t; Pd = 760 mg\t; Pt = 170 mg\t; Cu = 19,0 %; Au\Pd = 10; Pd\Pt = 4,5;
"Assarel" deposit: Au = 4800 mg\t; Pd = 54 mg\t; Pt = 14 mg\t; Cu = 27,9 %; Au\Pd = 88; Pd\Pt = 3,8.

The contents of minor components are higher (Table 3 and 4) as compared to the porphyry copper deposits Bor, Midanpeck (Serbia), Sar Cheshme (Iran), Sayak (Kazachstan), El Salvador (Chile), Bute (USA) and others (Tarkian and Stribtny, 1999).

The present studies show that the contents of minor components should be taken into consideration in the balance of the reserves of porphyry copper deposits, in the produced ore and in the flotation concentrates. This will allow to plan in advance the extraction technology and its value in order to increase the efficiency of mining works and to utilize the ores more completely. The studies carried out will help to undertake practical steps to extract these valuable minor components during the metallurgical processing of the produced concentrates.

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