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PRYMARY GEOCHEMICAL HALO OF “ELATSITE” PORPHYRY COPPER DEPOSIT

K. Popov, G. Georgiev
University of Mining and Geology “St. Ivan Rilski”, 1700, Sofia, e-mail: kpopov@mgu.bg, ggeorgiev@mgu.bg

РЕЗЮМЕ. Изследването на първичния геохимичен ореол в района на находище Елаците е извършено чрез 198 проби. Статистическият анализ показва, че елементите Cu, Au и Mo имат повишени съдържания в палеозойските гранитоиди, хорнфелзите и в Елашкия интрузив. Освен това, в палеозойските гранитоиди се установяват сравнително по-ниски съдържания на Pb и Ni. Старопалеозойските филити се отличават с повишени концентрации на Zn, Pb, Mn, V, и Ti. Хорнфелзите се характеризират и с относително високо съдържание на Co, V, Ti и Mn. Горнокредният интрузив се характеризира с повишени съдържания на Cr, Ni, V, Ti и Co. Съдържанията на Ag, Bi и As са сравнително еднакви в различните скали от участъка на находището.

На базата на факторен анализ са изведени следните три геохимични асоциации: ([Ni, Cr]) Co, V, Ti); ([Cu] Au, Ag) и [Zn, Pb, Mn]. Разпространението на асоциацията от главните рудни елементи ([Cu] Au, Ag) е сходно с контурите на рудното тяло и се определя от разпространението на кварц-пирит-халкопиритовата и кварц-магнетит-борнит-халкопиритовата минерални парагенези. Главните минерали, обуславящи появата на тази геохимична асоциация са халкопиритът, борнитът, златото и електрума. Геохимичната асоциация ([Ni, Cr]) Co, V, Ti) е локализирана предимно в метаморфните скали от периферните части на рудничната кариера и извън нея. Тези еленменити присъстват главно като изоморфни примеси в пирита, чието развитие в голяма степен съвпада с ареала на разпространение на кварц-пиритната минерална парагенеза. Ореолът на геохимичната асоциация [Zn, Pb, Mn] е развит около кариерата на рудник Елаците, като проявата му е свързана основно с развитието на кварц-галенит-сфалеритовата минерална парагенеза. Основните минерали, с които е свързана тази геохимична асоциация, са сфалеритът, галенитът и манганокалцитът. Трите геохимични асоциации показват подчертано зонално площно разпространение, което вероятно е обусловено от зоналното развитие на рудните минералните асоциации.

ПЪРВИЧЕН ГЕОХИМИЧЕН ОРЕОЛ НА МЕДНО-ПОРФИРНОТО НАХОДИЩЕ “ЕЛАЦИТЕ”

К. Попов, Г. Георгиев
Минно-геоложки университет “Св. Иван Рилски”, 1700 София, e-mail: kpopov@mgu.bg, ggeorgiev@mgu.bg

ABSTRACT. The study of the primary geochemical halo in the area of Elatsite ore deposit is done by 198 samples. The statistical analysis show that the chemical elements Cu, Au and Mo posses higher contents in the Paleozoic granite and hornfels and in the Elatsite intrusive. Besides, increased contents of Pb and Ni are determined within the Paleozoic granite. The Early Paleozoic phyllite is characterized with raised contents of Zn, Pb, Mn, V, and Ti. The hornfels possess the relatively higher contents of Co, V, Ti and Mn. The Late Cretaceous intrusive is characterized by higher contents of Cr, Ni, V, Ti and Co. The Ag, Bi and As contents are comparatively equal within the different rocks from the ore deposit’s.

The following three geochemical associations are determined by factor analysis: ([Ni, Cr]) Co, V, Ti); ([Cu] Au, Ag) and [Zn, Pb, Mn]. The association of main ore elements ([Cu] Au, Ag) is identically distributed to the contour of the ore body. It is determined by the spreading of the quartz-pyrite-chalcopyrite and quartz-magnetite-bornite-chalcopyrite mineral parageneses. The main minerals determining the manifestation of this geochemical association are chalcopyrite, bornite, native gold and electrum. The geochemical association ([Ni, Cr]) Co, V, Ti) is localized predominantly in the metamorphic rocks from the peripheral part of the open pit and outside of it. These elements are presented mainly as isomorphous impurities in the pyrite, which development coincides to a great extent with the spreading area of the quartz-pyrite mineral paragenesis. The aureole of the geochemical association [Zn, Pb, Mn] is developed around the Elatsite open pit. Its manifestation is related mainly to the development of the quartz-galena-sphalerite mineral paragenesis. The three geochemical associations manifest markedly zonal development, which is determined probably by the zonal widespread of the ore mineral’s associations.

Introduction

The Elatsite porphyry copper deposit is situated about 55-60 km eastern from the city of Sofia and about 6 km southern from the town of Etropole. It is formed within the frame of the Elatsite-Chelopech volcano-intrusive complex (Popov et al., 2001). The position of the deposit is controlled by the Late Cretaceous Elatsite quartzmonzodiorite to granodiorite porphyry intrusive. It is intruded within the Early Paleozoic low grade metamorphosed rocks and the Early Carboniferous Vejen granitic pluton. The metamorphite is contact matamorphosed to hornfels and spotted phyllite along the exocontact zone of the pluton.

The objective of this study is to determine the geochemical associations in Elatsite deposit and to trace their spatial distribution. Statistical methodology for assessment of the geochemical associations, described by Popov (2003), is used. The methodology investigates the common spatial distribution of the chemical elements and their grouping, on the basis of their correlations.

Data Used

The results from determination of the chemical element’s contents in the primary geochemical haloes of Elatsite deposit are used for the study of the geochemical associations. The sampling is done during 2000-2001 by G. Georgiev, as totally 206 samples from the open pit and the area around the deposit was taken. All rock types observed in the area was sampled, and the sample locations are shown further in fig.3. The samples are analyzed in the “Geochemistry” laboratory at the University of Mining and Geology “St. I. Rilski” by ICP-AES analysis as well as by AAS analysis for Au, Ag and Cr. The contents of 18 elements are determined: Au, Ag, Cr, Pb, Zn, Cu, Ni, Bi, Mn, As, Co, Mo, V, Ti, Sb, Sn W and Ba, as the last four elements are not found in neither of the samples.

Table 1.
Statistics for distributions of studied elements, calculated from all samples

	Mean	Median	Minimum	Maximum	Variance	Standard	Skewness	Kurtosis
Au	0.128	0.099	0.015	0.85	0.0142	0.119	2.4544	8.8860
Ag	0.381	0.250	0.250	2.90	0.1342	0.366	3.9115	17.9135
Cr	26.793	23.750	0.025	274.40	837	28.939	5.6627	40.7613
Pb	20.856	19.500	0.200	65.30	178	13.326	1.1205	1.5818
Zn	47.700	38.700	7.730	321.00	980	31.302	4.1775	29.4972
Cu	1250.270	369.300	2.000	10718.00	3051866	1746.959	1.9002	4.4512
Ni	29.728	19.450	4.600	234.00	865	29.405	3.9125	22.3315
Bi	11.418	5.000	5.000	62.00	143	11.952	2.1150	4.1991
Mn	320.779	222.300	4.900	1611.00	83699	289.308	2.0335	4.6701
As	9.682	5.000	5.000	241.50	411	20.284	8.5280	89.4184
Co	15.804	13.950	0.200	56.00	80	8.930	1.3460	3.2720
Mo	16.932	2.020	0.250	437.81	1962	44.291	5.9918	46.5708
V	178.196	154.000	22.000	414.00	7367	85.829	0.6734	-0.3203
Ti	3308.880	2862.500	426.000	7634.00	2571379	1603.552	0.6709	-0.3194

Table 2.
Statistics for distributions of studied elements, calculated from subsets for individual rock types

	Mean	Median	Minimum	Maximum	Variance	Standard	Skewness	Kurtosis
	Early Paleozoic phyllite (25 samples)							
Au	0.062	0.056	0.015	0.178	0.0020	0.045	0.6973	-0.0751
Ag	0.264	0.250	0.250	0.600	0.0049	0.070	5.0000	25.0000
Cr	30.024	26.400	15.200	98.500	242	15.559	3.8197	16.8237
Pb	26.704	23.900	8.000	59.500	185	13.599	0.6990	0.1008
Zn	77.334	89.100	16.100	133.800	1402	37.445	-0.1756	-1.5348
Cu	85.824	35.600	8.600	473.900	9969	99.845	2.6664	9.1082
Ni	45.140	47.300	5.700	101.100	394	19.839	0.2509	2.0491
Bi	16.655	5.000	5.000	55.900	289	17.013	1.2814	0.4522
Mn	589.248	494.700	4.900	1449.000	196339	443.101	0.4463	-0.9129
As	13.116	5.000	5.000	87.100	299	17.278	3.5774	14.7207
Co	15.476	13.700	0.200	38.000	86	9.259	0.5195	0.2523
Mo	0.790	0.630	0.250	3.390	1	0.743	2.3312	6.0287
V	262.051	307.000	38.000	414.000	10584	102.877	-0.9990	-0.0287
Ti	4933.720	5682.000	717.000	7634.000	3685395	1919.738	-1.0248	0.0174
	Hornfels (62 samples)							
Au	0.113	0.109	0.015	0.36	0.0032	0.057	1.7306	6.0363
Ag	0.341	0.250	0.250	1.50	0.0768	0.277	3.1142	8.9515
Cr	34.018	22.150	5.400	274.40	2101	45.835	4.1631	17.7192
Pb	23.747	20.700	0.200	65.30	255	15.970	1.0849	0.4540
Zn	40.179	36.050	17.700	105.20	285	16.890	1.2505	2.1933
Cu	886.573	258.500	35.200	10718.00	2993867	1730.279	4.1382	19.7209
Ni	52.652	43.600	19.900	234.00	1453	38.124	3.8624	15.0330
Bi	13.812	5.000	5.000	62.00	198	14.083	1.7862	2.7086
Mn	337.884	302.600	31.100	980.00	49670	222.867	1.1121	0.8293
As	10.542	5.000	5.000	241.50	936	30.601	7.3128	55.5769
Co	22.046	19.650	6.300	56.00	103	10.139	1.3088	2.0716
Mo	12.550	2.310	0.250	130.40	554	23.535	3.2514	12.3318
V	223.493	224.500	29.000	405.00	7132	84.452	-0.1121	-0.5796
Ti	4066.532	4047.000	541.000	7482.00	2567077	1602.210	-0.0991	-0.6551
	Early Carboniferous granodiorite – Vejen pluton (68 samples)							
Au	0.150	0.112	0.015	0.848	0.0248	0.157	1.9742	5.2629
Ag	0.454	0.250	0.250	2.900	0.2120	0.460	3.4168	13.6971
Cr	29.915	30.200	11.200	66.200	82	9.029	0.5480	2.7803
Pb	16.886	16.100	0.200	64.700	114	10.659	1.3184	4.7944
Zn	47.576	38.700	7.730	321.000	1513	38.903	5.6018	37.4771
Cu	1892.901	1618.000	2.000	5198.000	3429595	1851.917	0.4401	-1.3100
Ni	14.945	15.250	4.600	22.000	16	4.014	-0.3350	-0.2514
Bi	7.732	5.000	5.000	34.100	42	6.508	2.6677	6.7193
Mn	264.536	193.850	25.700	1464.000	48425	220.058	2.9276	12.6007
As	7.787	5.000	5.000	59.500	95	9.760	4.0958	16.9738
Co	12.186	12.450	0.200	27.400	22	4.678	-0.0198	1.8357
Mo	30.053	5.095	0.250	437.810	4729	68.766	4.0930	19.7547
V	143.883	136.500	31.840	355.000	1940	44.051	1.5554	6.9787
Ti	2716.791	2552.500	587.800	6799.000	752974	867.741	1.5398	6.3416
	Late Cretaceous quartz-monzodiorite porphyrite, granite porphyry (43 samples)							
Au	0.151	0.109	0.015	0.641	0.0170	0.131	1.7159	3.6186
Ag	0.393	0.250	0.250	2.100	0.1577	0.397	3.6536	13.5865
Cr	9.559	5.600	0.025	88.700	205	14.326	4.3036	22.6348
Pb	19.562	21.100	0.200	48.400	116	10.759	0.1641	0.1699
Zn	41.512	37.300	16.790	106.800	321	17.903	2.0034	4.5488
Cu	1435.421	579.000	18.000	5804.000	2783659	1668.430	1.3152	0.6189
Ni	11.090	8.660	4.720	38.300	67	8.213	2.4889	5.2634
Bi	10.749	5.000	5.000	40.000	102	10.091	1.5920	1.2191
Mn	228.972	150.500	9.200	1611.000	73920	271.883	3.7312	16.4639
As	9.444	5.000	5.000	95.600	233	15.274	4.7346	25.0894
Co	12.716	11.500	1.200	29.900	52	7.236	0.5108	-0.6716
Mo	11.885	2.330	0.250	80.800	365	19.096	2.2788	4.8498
V	118.395	124.000	22.000	240.000	2270	47.640	0.2991	0.5389
Ti	2208.102	2301.000	426.000	4433.000	798474	893.574	0.3051	0.4354

The computerized pre-processing of the data was done, and 8 outlier samples with highly increased contents for some of the elements are excluded. After the reduction of the outliers, the final number of the samples used in this investigation is 198.

The data is imported in ArcView Geographic Information System, which is used for some spatial analyses and map preparation. The statistical processing and analysis of the data are done mainly with Systat software.

Univariate Statistics

Univariate statistical analysis is performed on the data for the contents of separate chemical elements. The aim is to receive primary information for the average contents of elements, the degree of their variability and the shape of their statistical distributions. This analysis is performed on the massif of all data as well as on subsets for the separate rock types, and the result is shown in tables 1 and 2 respectively. The elements possess markedly asymmetrical shapes of distribution and high variances as a whole, as it is visible on these two tables. Such characteristics of the statistical distributions are often observed at the analysis of geochemical haloes and they reflect the presence of non-equilibrium physical-chemical systems with the import of ore substance from the elapsed ore-forming processes (Popov, 2003).

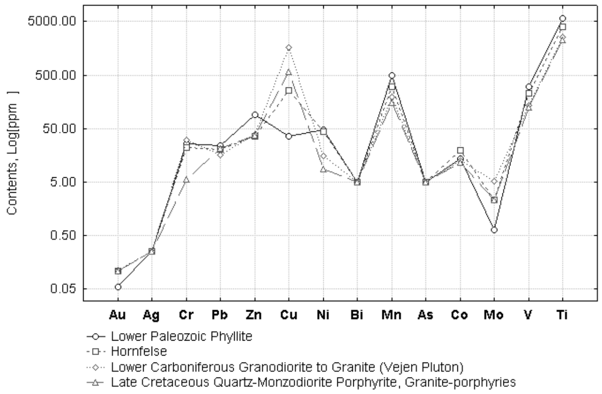

Fig. 1. Concentrations of the studied elements within the individual rock types. The average contents are estimated by the median values (tab. 2)

The usage of the median values is recommended for the estimation of average contents of elements, due to the asymmetrical shape of distributions. The variations of average contents in separate rock types are illustrated on fig. 1, where the contents are given in logarithmic scale on the Y-axis for better clearness. The phyllite is differ in higher concentrations of Zn, Pb, Mn, V, Ti and somewhat of Ni in comparison with the rest of rocks, as well as in lower contents of Cu, Au and Mo. The increased concentrations of Pb and Zn within the phyllite could be explained by reason that these ore elements are spreaded mainly in the periphery and upper levels of the deposit (Hadjyiski et al., 1970f). The elements Cu, Au and Mo manifest markedly higher concentrations in magmatic rocks and hornfelses, which are ore-bearing rocks. Highest contents of Cu and Mo are observed within the granodiorite of Vejen pluton, due to its increased jointing and permeability, which determine it as most favorable environment for ore precipitation. Lower concentrations of Pb and Ni are observed in the rocks from Vejen pluton as well. The hornfelse is characterized with relatively higher contents of Co, V, Ti and Mn, whereas lower concentrations of Cr, Ni, V, Ti and Co are representative of the Upper Cretaceous granitoide. The determined concentrations of Ag, Bi and As are comparatively the same in the four rock types developed within the deposit's area.

Determination of the geochemical associations

The geochemical association's determination is performed by statistical methodology, based mainly on factor and cluster analyses (Popov, 2003). The groups of elements which concentrations possess similar spatial variations are interpreted as geochemical associations. The similarities in the spatial behavior of elements are estimated by their correlations. The following geochemical associations are determined by factor analysis:

([Ni, Cr] Co, V, Ti),
([Cu] Au, Ag) and
[Zn, Pb, Mn].

The correlation coefficients between the elements are shown in table 3, and the grouping of the elements and their factor loadings are represented on figure 2 and table 4.

The first group of elements ([Ni, Cr] Co, V, Ti) has highest contribution to the total variability of data, as Ni and Cr possess highest loadings in this association. The associations ([Cu] Au, Ag) with highest loading of the copper and [Zn, Pb, Mn] are clearly distinguished as well. The elements Ti, V and As

Table 3.

Correlation matrix showing the relations between the elements. The statistical significance threshold is r = 0.14, at 198 samples and 5% probability of error

	Au	Ag	Cr	Pb	Zn	Cu	Ni	Bi	Mn	As	Co	Mo	V	Ti
Au	1.00													
Ag	**0.40**	1.00												
Cr	0.08	0.06	1.00											
Pb	**-0.19**	-0.05	-0.01	1.00										
Zn	**-0.20**	-0.03	0.10	**0.50**	1.00									
Cu	**0.70**	**0.42**	**0.32**	**-0.29**	**-0.19**	1.00								
Ni	-0.04	-0.03	**0.79**	**0.18**	**0.17**	0.08	1.00							
Bi	-0.08	**-0.14**	-0.07	**0.20**	0.06	**-0.26**	0.10	1.00						
Mn	**-0.28**	-0.08	0.05	**0.45**	**0.59**	**-0.29**	**0.26**	0.09	1.00					
As	0.04	0.10	-0.04	0.13	0.08	-0.01	-0.00	0.00	0.11	1.00				
Co	-0.09	-0.06	**0.48**	**0.14**	0.10	0.02	**0.69**	0.05	**0.25**	-0.05	1.00			
Mo	0.13	0.06	**0.17**	**-0.17**	-0.11	**0.34**	0.02	-0.10	**-0.17**	-0.05	0.02	1.00		
V	**-0.24**	**-0.20**	**0.40**	**0.45**	**0.38**	**-0.26**	**0.67**	**0.20**	**0.53**	-0.01	**0.45**	-0.13	1.00	
Ti	**-0.25**	**-0.20**	**0.40**	**0.45**	**0.40**	**-0.26**	**0.65**	**0.20**	**0.54**	-0.02	**0.44**	-0.14	**0.99**	1.00

possess some tendency for grouping in the last association also (table 4), which is probably because of the overlapping in associations' spreading.

Interpolation on the factor scores of individual samples is done for determination of the spatial distribution of the geochemical associations. Inverse distance method is used. The spatial distribution of the associations (fig. 3) determines a clear zonal spreading of the elements.

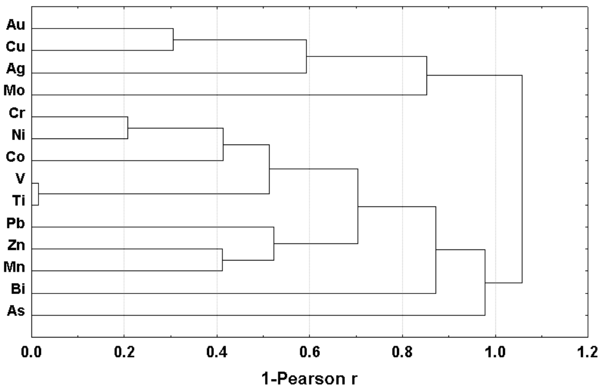

Fig. 2. Dendrogram representing the grouping of elements by cluster analysis

Table 4.
Factor loadings representing the grouping of elements by factor analysis

	Factor 1	Factor 2	Factor 3
Au	-0.035168	**0.778029**	-0.103322
Ag	-0.097774	**0.718429**	0.190937
Cr	**0.825295**	0.258968	-0.104257
Pb	0.139907	-0.189788	**0.730372**
Zn	0.150360	-0.084575	**0.755168**
Cu	0.134623	**0.854868**	-0.238600
Ni	**0.935018**	0.023068	0.079979
Bi	0.068793	-0.341039	0.118484
Mn	0.260266	-0.225467	**0.724095**
As	-0.146521	0.215633	***0.407036***
Co	**0.756308**	-0.049836	0.004695
Mo	0.131348	0.304444	-0.305533
V	**0.732427**	-0.323186	***0.440608***
Ti	**0.726051**	-0.323082	***0.447787***
Explained variance	3.373265	2.480680	2.417103
Proportion of total	0.240948	0.177191	0.172650

Ore mineral associations

The mineral composition of Elatsite deposit is subject of investigations by different authors (Hadjyiski et al., 1970f; Dimitrov and Koleva, 1975; Bogranov, 1987; Dimitrov, 1988; Petrunov et al., 1992; Petrunov and Dragov, 1993; Tokmakchieva, 1994; Dragov and Petrunov, 1996; Strashimirov et al., 2002; Tarkian et al., 2003). Based on the data from these studies Strashimirov et al. (2002) distinguish the following consecutively formed mineral paragenetical associations in the deposit: quartz-magnetite-bornite, quartz-pyrite-chalcopyrite, quartz-molybdenite, quartz-pyrite (±calcite), quartz-galena-sphalerite, quartz-calcite-zeolite and supergene covelline-chalcocite.

The quartz-magnetite-bornite-chalcopyrite paragenesis is manifested in form of lenses and veinlets. It is observed mainly in thenorth-eastern parts of the open pit currently, within the frames of Vejen pluton. Rutile, ilmenite and numerous Co, Ni, Te, Bi, Se, Au and Ag bearing rare minerals are presented, besides the magnetite and bornite. The presence of PGM and coarse-grained native gold, which is non-specific for the deposit, is characteristic feature (Dimitrov and Koleva, 1975; Petrunov et al., 1992; Petrunov and Dragov, 1993; Dragov and Petrunov, 1996). The gold possesses higher content of Ag (Tarcian et al, 2003; Georgiev, unpubl.).

The quartz-pyrite-chalcopyrite paragenesis is of major economical interest. It is developed as veinlets, compact aggregates and disseminations. It is spread predominantly in the central parts of ore body and additionally enriches the previous paragenesis with Cu, Au and Mo. The chalcopyrite/pyrite ratio in the flotation concentrate is determined as 10:1 (Tarcian et al., 2003). Little molybdenite and Co, Ni and Pd bearing minerals-impurities are observed (Dragov and Petrunov, 1996). The gold is represented by electrum predominantly (Tokmakchieva, 1982; Strashimirov and Kovatchev, 1994; Tarcian et al., 2003; Georgiev, unpubl.).

The quartz-molybdenite paragenesis is represented by veinlets, which cuts the minerals from the previous parageneses. It is developed mostly in the central part of the deposit.

The quartz-pyrite (±calcite) paragenesis is veins and veinlets in shape, developed in the outern and upper parts of the deposit. Limited quantities of chalcopyrite are observed as well.

The quartz-galena-sphalerite paragenesis is rare and it is observed in outer south-western parts of the deposit only (Hadjyiski et al., 1970f). It is also vein in type. Sphalerite and galena are typomorphic minerals for this paragenesis, and the quantities of pyrite, chalcopyrite, tenantite and markazite are limited and very changeable. Calcite (manganese calcite) is observed as gangue mineral.

The quartz-calcite-zeolite paragenesis is formed during the later stage of hydrothermal activity in the deposit. It is represented by fine veinlets, in which the redeposited chalcopyrite and pyrite are observed also. Limited quantities of fluorite are determined as well.

The covelline-chalcocite paragenesis is a product of the supergene stage of the mineral forming process. It is limited developed in the upper parts of the deposit, down to 50-60 m below the surface. This oxidation zone is studied mainly by Tokmakchieva (1981, 1983, 1994) and Tokmakchieva and Dragov (1985), as claudetite, chalcophyllite, lybetenite, tenardite, chalcocite, malachite, azurite, limonite, etc. are determined.

Spatial distribution of the geochemical associations

The spreading of the economically most important for the deposit geochemical association ([Cu] Au, Ag) is similar to the contours of the ore body and it is determined mainly by the development of the quartz-pyrite-chalcopyrite and quartz-magnetite-bornite-chalcopyrite parageneses. The chemical elements from this association are presented by chalcopyrite $CuFeS_2$, bornite Cu_5FeS_4, native gold and electrum.

The geochemical association ([Ni, Cr]) Co, V, Ti) is located mainly within the metamorphic rocks, out of the ore body, in the peripheral parts of the open pit and outside of it. The main mineral bearer of these elements is the pyrite, which quantity is raised in these parts and coincides predominantly with the

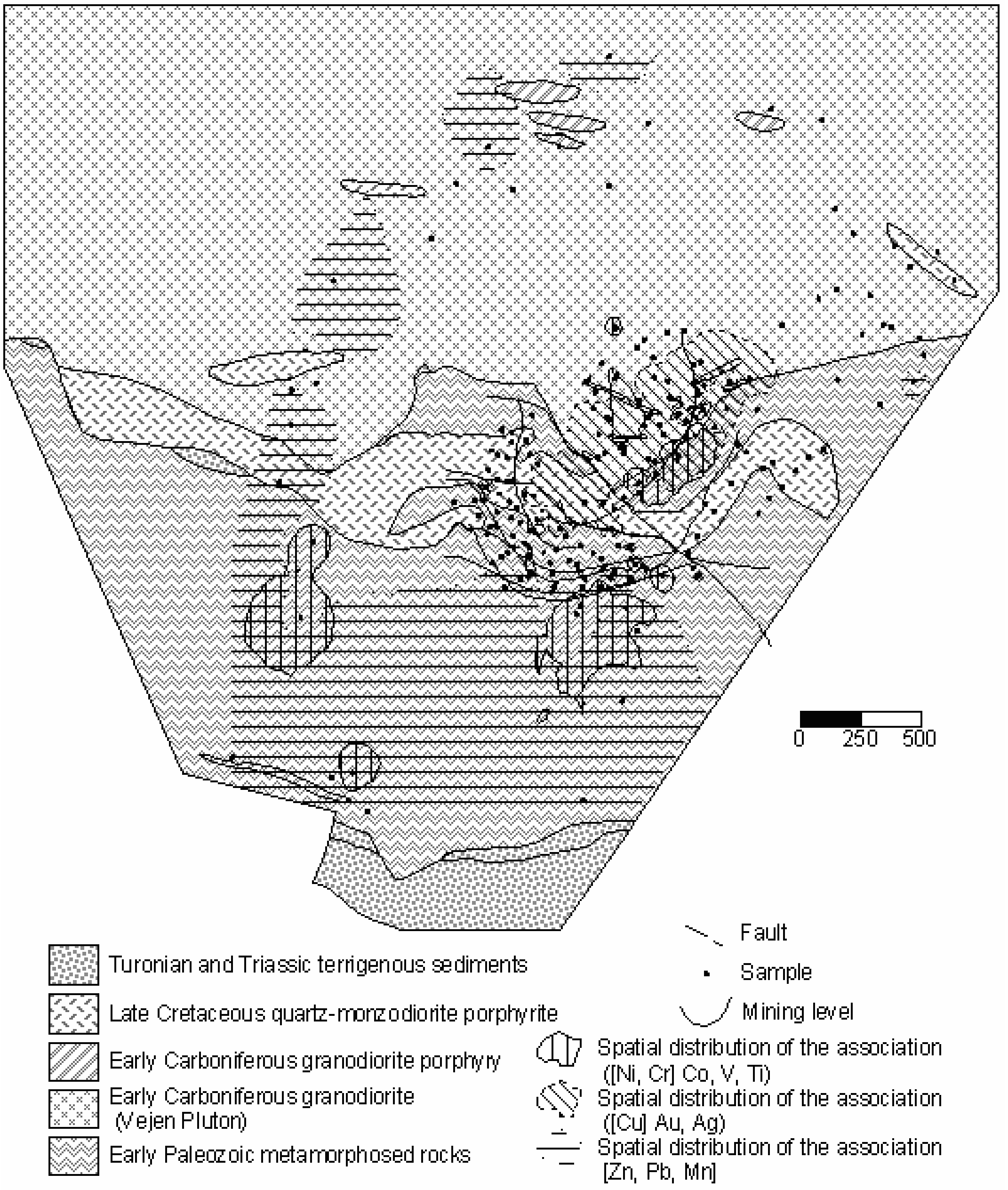

Fig. 3. Spatial distributions of the geochemical associations, determined on the basis of factor analysis

spreading of quartz-pyrite paragenesis. The chemical analyses of mono-mineral samples from pyrite show average contents 0.0309 % Co and 0.0055 % Ni (Hadjyiski et al., 1970f). The cobalt and the parageneticaly related to it nickel are included as isomorphous impurities in the pyrite, replacing the iron in it (Dimitrov, 1988). Tarcian et al. (2003) investigate pyrite from the quartz-pyrite-chalcopyrite paragenesis and determine nickel and cobalt pyrite with contents of 0.5-6.7 wt.% Ni and 1.6-14.9 wt.% Co respectively, which also confirm the participation of these elements in the contents of pyrite in the deposit. The vanadium participates in the composition of pyrite, chalcopyrite and bornite, replacing the iron in them Tokmakchieva (1994). Probably the chromium and titanium also participate in the composition of the pyrite as isomorphous impurities, replacing the iron in it. It should be mentioned that according to Tokmakchieva (1994), V, Ti and Cr didn't presented in the hydrothermal solution coming from depth, but they are derived from the country rocks.

The aureole of [Zn, Pb, Mn] geochemical association is developed around the Elatsite open pit. Its manifestation is related mainly to the development of quartz-galena-sphalerite paragenesis. Sphalerite (ZnS), galena (PbS) and manganese calcite are the main minerals bearing the elements from this geochemical association. The manganese, which didn't participate in the hydrothermal process, migrates from the country rocks at influence of the hydrothermal solutions, and it accumulates in the calcite transforming it to manganese calcite (Tokmakchieva, 1994).

Conclusions

The analysis of samples from primary geochemical halo from the open pit and area around the Elatsite deposit shows that the main ore elements Cu, Au and Mo possess clearly higher concentrations in the ore-hosting Paleozoic and Late

Cretaceous intrusives and hornfels in comparison to Lower Paleozoic phylite. The phylite is distinguished with raised concentrations of Zn, Pb, Mn, V and Ti, and with relatively lower contents of the main ore elements. The hornfels is characterized by relatively higher contents of Co, V, Ti and Mn also, while comparatively lower concentrations of Cr, Ni, V, Ti and Co are representative for the Elatsite intrusive. The determined concentrations of Ag, Bi and As are relatively equal in the four rock types from the deposit's area.

The following geochemical associations in the primary geochemical halo of the deposit are determined on the basis of factor analysis:

([Ni, Cr]) Co, V, Ti); ([Cu] Au, Ag) and [Zn, Pb, Mn], while the molybdenum remains independent.

The pointed out three geochemical associations have markedly zonal distribution, which is probably determined by the zonal development of the ore mineral parageneses. The spreading of the ([Cu] Au, Ag) association of main ore elements is similar to the contours of the ore body and it is determined by the development of the quartz-pyrite-chalcopyrite and quartz-magnetite-bornite-chalcopyrite parageneses. The chalcopyrite, bornite, native gold and electrum are main minerals causing the manifestation of this geochemical association.

The geochemical association ([Ni, Cr]) Co, V, Ti) is located mainly within the metamorphic rocks, in the periphery of open pit and outside it. These elements are represented mainly as isomorphous impurities in the pyrite (Hadjyiski et al., 1970f; Dimitrov, 1988; Tarcian et al., 2003; Tokmakchieva, 1994), which quantity increases in these parts and coincides mainly with the spreading area of quartz-pyrite paragenesis.

The [Zn, Pb, Mn] association is developed around the Elatsite open pit, actually out of the ore body, as its manifestation is related to the presence of the quartz-galena-sphalerite paragenesis. The chemical elements from this association occur in form of the minerals sphalerite, galena and manganese calcite.

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