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ZONAL DISTRIBUTION OF ELEMENTS IN THE ORE FIELD OF BANSKÁ ŠTIAVNICA

(Figs. 1—15)

A b s t r a c t: In this paper the distribution of trace elements in the complex of neovulcanites is presented. Primary aureoles are treated in subsurface parts of the deposit and vertical zonation of trace elements in rocks surrouding the ore veins is presented. Secondary aureoles of trace elements are studied from an area, where the course of ore structures is supposed.

Introduction

In Central Slovakia in the ore district of Banská Štiavnica we studied distribution of trace elements in the complex of neovulcanites near the ore veins with polymetallic Pb-Zn-Cu mineralization under and on the surface in places of supposed course of ore structures.

The ore district of Banská Štiavnica is extensive with a large number of ore veins (fig. 1), we therefore limited the study of primary aureoles to the neighbourhood of some veins, especially of rock crosscuts striking across the veins and making possible to observe changes in representation of trace elements to a greater distance from the veins. In the studied sections of the profiles we have got zonation of the vein filling at the deposit in vertical direction from the „upper, so called Pb-Zn zone" through the so called „lower Pb-Zn zone", the „upper zone of Cu" (M. K o d ě r a 1956—1963). We traced the elements of Pb, Zn, Cu, Ba, Ag, Ni, Co, Sr, Li, V, Zr, Ga, Sc, La, Mo, Hg, Sn, in series of samples taken near the veins in intervals of 10 to 20 cm, with larger intervals in greater distance from the veins. The elements were determined by the method of quantitative spectral analysis on spectrograph E 492, with slot wide 20, height 2 mm, two degree filter 100/10 %.The spectra were registered on photographic plate Agfa Blau Extrahart.

We studied secondary aureoles of dispersion of elements in places of supposed course of vein structures between the communities of Banská Belá and Podhorie, south of the community of of Sitnianka and north of the community of Anton (fig. 1). We also traced the elements of Ag, Pb, Zn, Cu and also Au in some samples. We choose the method of three parallel profiles 100 m apart in order to exclude occasional mistake of sampling. The samples were taken along the profile in intervals of 10 to 20 cm from the depth of 70 to 100 cm from deluvial waste. The elements were determined by semiquantitative spectral analysis by aid of S. p. d. scale. In S. p. d. scale quantitative values were determined for Ag 0.01 %, for Cu 0,01 %, Pb 0.02 %, Zn 0.02 %. The presence of Au was positively determined in one sample only. These values (except Ag) approximately coincide with phone contents for the northern margin of the ore field of Banská Štiavnica according to J. N o v o t n ý (1958). We treated the analyses in a statistical way and the phone content was determined in values of S. p. d.

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I. Primary Aureoles

Brief Characterization of Altered Rocks

Young volcanic rocks in the ore district of Štiavnica were penetrated with post-volcanic solution, as a result of which in the rocks alternation of primary minerals and formation of secondary minerals took place. This process was studied from petrographic aspect and also from the aspect of changes of chemism with employing of silicate analyses by J. Forgáč (1966, 1967) on the same profiles as the trace elements in the work presented.

The mostly wide spread alteration in the area of B. Štiavnica is chloritization. In this alteration chloritization of dark-coloured minerals (pyroxene, amphibole, biotite), formation of pyrite and a small amount of carbonate, sericite and quartz took place, the plagioclasses almost remain fresh. The original composition of rocks essentially remains unaltered. Chloritization is spread „regionally" and does not show zonation in relation to the course of ore veins.

Near the vein adularization, sericitization and silicification are of zonal position. Between these zones there is gradual transition. The most distant zone following the course of the veins is adularization. It was manifested by metasomatic replacement of plagioclase by adular (in places also of chlorite). The rocks are enriched in potassium and from the rocks natrium is carried away. Adularization was more intensely manifested near the veins with the ore filling of the middle and lower Pb-Zn zone. In Cu zone enrichment of rocks in potassium diminishes and may even show tendency of carrying away from the rocks. Nearer to the vein behind the zone of adularization the zone of sericitization was evident. It is characterized by intense formation of sericite, which mainly replaces plagioclase and adular. This zone is only several metres wide and in places overlaps the zone of adularization and silicification. In the zone of sericitization rocks are enriched in potassium and silica and from the rock Fe, Mg, Al, Na, Ca, are carried away. In close proximity of the veins there is a relatively narrow zone of silicification distinct from the petrographic and chemical side. In the rock formerly originated minerals are replaced by quartz as a result of what the rocks are more intensely enriched in silica and Al, Ca, Na, Fe and Mg are carried away.

Accompaning secondary minerals in the zone of adularization, sericitization and silicifization are chlorite, carbonate, sericite, quartz, epidote-zoisite, pyrite and limonite. Their propotionate representation in the individual zones is changing.

Trace Elements in the Rocks

We studied representation of trace elements in pyroxenic andesite, dacite and quartz diorite. In pyroxenic andesite near the Terézia Vein in the Maxmilian Pit in the 1th, 5th, and 12th horizon and near the Rozália Vein in the 12th horizon. In dacite in the Michal Pit in the 12th horizon near the underlying Bieber Vein and near the Rozália Vein in the Bakaly cross adit. In quartz diorite near the Terézia Vein in the Ferdinand adit. In the study of the mentioned cross adits across the veins 186 samples where analyzed and the results of the analyses are summarized in table 1, for each type of rocks the range of the content of trace elements is mentioned. In table 2 the average content of trace elements in rocks is mentioned. In column, I for each type of rocks representation of elements in places more distant from the veins is mentioned, where the

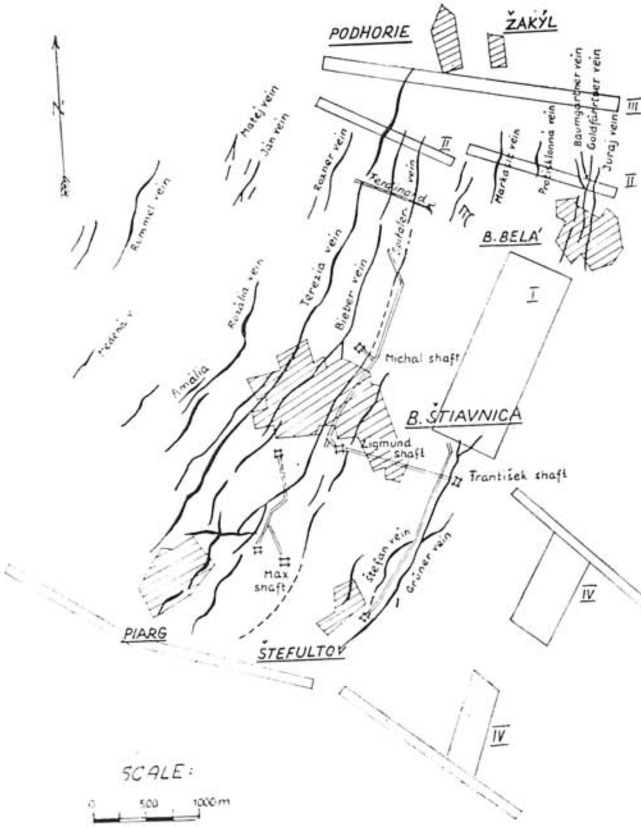


Fig. 1. Sketch-map of the veins of Banská Štiavnica (according to F. Szabo) with indicated places of study of primary and secondary aureoles od dispersion. I — Area of study of secondary aureoles in northern continuation of the Grüner Vein, II—III — Area of study of secondary aureoles in northern continuation of the principal veins. IV — Area of study of secondary aureoles in the area north of Antol. V — Area of study of secondary aureoles in southern termination of the veins.

rocks are chloritized and in column II representation of elements near the veins, where the rocks are silicified, sericitized and adularized is shown.

Total representation of trace elements shows their amount in pyroxenic andesite, dacite and quartz diorite in places more distant from the veins to be almost equal, what permits to apply equal criterii for the study of higher or lower representation of elements in these rocks near the veins and to determine the width of primary aureoles near the veins in various horizons of the deposit.

Zonal Distribution of Trace Elements Around the Veins

Representation of elements in rocks around the veins was studied on profiles in various horizons of the deposit on various veins.

We ordered the studied profiles vertically according zonation of the vein filling, in which way we have got the total profile of the deposit through the Pb-Zn zone and Cu zone (fig. 2 to 6). On the basis of such ordered data of representation of trace elements in rocks we present the picture of distribution of elements around the veins in the ore district of B. Štiavnica. A part of the studied elements around the veins forms a distinct zonation, some elements show only slight indications of zonation while a part of

Table 1. Representation of Trace Elements in Rocks (%)

Analysed by J. Cubínek, Dionýz Štúr Institute of Geology, Bratislava

	Pyroxenic andesite		Dacite		Quartz diorite	
	I	II	I	II	I	II
Pb	0,002 — 0,007	0,008 — 0,10	0,003 — 0,006	0,008 — 0,10	0,005 — 0,010	0,018 — 0,10
Zn	0,004 — 0,008	0,010 — 0,3	0,005 — 0,006	0,022 — 0,3	0,005 — 0,009	0,010 — 0,3
Cu	0,001 — 0,006	0,007 — 0,03	0,001 — 0,006	0,009 — 0,03	0,001 — 0,007	0,001 — 0,007
Ba	0,022 — 0,1	0,1 — 1,0	0,047 — 0,1	0,016 — 0,50	0,035 — 0,1	0,13 — 0,50
Ag	0,0001 — 0,0002	0,0003 — 0,0008	0,0001 — 0,0003	0,0003 — 0,001	0,0001 — 0,0004	0,0004 — 0,001
Co	0,0007 — 0,002	0,0007 — 0,002	0,0007 — 0,002	0,0006 — 0,002	0,001 — 0,002	0,001 — 0,002
Ni	0,0006 — 0,003	0,0006 — 0,005	0,0006 — 0,001	0,0006 — 0,001	0,0008 — 0,001	0,0008 — 0,001
Sr	0,017 — 0,160	0,016 — 0,170	0,032 — 0,120	0,035 — 0,126	0,045 — 0,166	0,021 — 0,178
Li	0,009 — 0,020	traces — 0,026	0,006 — 0,010	traces — 0,010	0,010 — 0,020	0,009 — 0,026
Ga	0,0005 — 0,001	0,0005 — 0,001	0,0007 — 0,001	0,0005 — 0,001	0,0008 — 0,001	0,0005 — 0,001
V	0,008 — 0,052	0,007 — 0,040	0,010 — 0,027	0,011 — 0,030	0,020 — 0,052	0,019 — 0,040
Zr	0,004 — 0,016	0,004 — 0,014	0,005 — 0,020	0,008 — 0,019	0,007 — 0,013	0,007 — 0,013
Sc	0,002 — 0,004	0,002 — 0,004	0,002 — 0,004	0,002 — 0,004	0,003 — 0,006	0,003 — 0,006
Hg	0,00001 — 0,0001	0,00001 — 0,0001	0,00001 — 0,0001	0,00001 — 0,0001	0,00001 — 0,0001	0,00001 — 0,0001
Mo	0,0 — 0,009	0,0 — 0,009	0,0 — 0,003	0,0 — 0,003	0,0 — 0,004	0,0 — 0,004

I — Representation of trace elements in chloritized pyroxenic andesites, dacites and quartz diorites in greater distance of the veins.
II — Representation of trace elements in adularized, sericitized and silicified pyroxenic andesites, dacites and quartz diorites in proximity of the veins.

In the table anomalous representation of Pb, Zn, Cu in the 12th horizon of the Maxmilián Pit and of Ba in the Bakaly Cross Adit in places more distant from the veins is not included, it is mentioned in the text.

Table 2. Average Representation of Trace Elements (%)

	Pyroxenic andesite		Dacite		Quartz diorite	
	I	II	I	II	I	II
	a	b	c	d	e	f
Pb	0,005	0,041	0,0046	0,060	0,0065	0,030
Zn	0,007	0,085	0,0055	0,087	0,0066	0,034
Cu	0,005	0,008	0,0034	0,015	0,0062	0,0052
Ba	0,042	0,323	0,052	0,202	0,052	0,335
Ag	0,00019	0,0004	0,0002	0,00038	0,00016	0,00043
Co	0,0014	0,0015	0,00096	0,00092	0,0016	0,0015
Ni	0,0014	0,0020	0,00077	0,00090	0,00091	0,00090
Li	0,011	0,015	0,009	0,0080	0,012	0,016
Sr	0,096	0,072	0,067	0,097	0,088	0,111
Ga	0,00090	0,00087	0,00077	0,00081	0,00094	0,00085
V	0,024	0,022	0,019	0,018	0,036	0,033
Zr	0,0083	0,0076	0,0084	0,010	0,011	0,010
Sc	0,003	0,003	0,003	0,0027	0,0037	0,0041
Hg	0,00014	0,00014	0,00015	0,00014	0,00014	0,00015

I — Average representation of trace elements in chloritized pyroxenic andesites, dacites and quartz diorites in greater distance from the veins. II — Average representation of trace elements in adularized, sericitized and silicified pyroxenic andesites, dacites and quartz diorites in proximity of the veins.

In the average the anomalies of Pb, Zn, Cu in the 12th horizon of the Maxmilian Pit and in the Bakaly Cross Adit in places more distant from the veins were not included.

a — Average of 48 analyses; b — Average of 62 analyses; c — Average of 17 analyses; d — Average of 22 analyses; e — Average of 18 analyses; f — Average of 19 analyses.

elements does not manifest indications of zonal distribution around the veins. Zonal distribution of elements around the veins is manifested as follows:

Lead is represented in thousandths and hundredths and near the veins its content in places increases to one tenth of percent. Highest concentrations where found up to 0.1 %. According to the content of Pb we distinguished two zones in the rocks (fig. 2). The first zone with content of Pb of 0.05 to 0.1 % is situated near the veins, its width is changing. Near the veins with ore filling corresponding to Pb-Zn zone in underlying rocks it attains maximum width of 25 m and only 2—3 m in overlying rocks. In Cu zone its width varies from 1.5 to 2.5 m. The second zone width content of Pb 0.01 to 0.05 % is also variously wide. In Pb-Zn zone its maximum width is 17 m in overlying rock and 35 m in rocks underlying the veins while around the Cu zone it narrows and attains maximum of 7.5 m. Higher representation of Pb (0.05 to 0.1 %) was proved in 12th horizon of the Maxmilian Pit in rock underlying the Terézia Vein in the section of 20 to 70 m from the vein. i. e. in places where pyroxenic andesite is pierced by dikes of dacites. Behind the delimited zones Pb content in rocks varies within the range of 0.002 to 0.01 %.

Zinc is in greater distance from vein present in rocks in thousandths of per cent and frequently its presence has not been identified. In proximity of the veins the content of Zn increases to tenths of per cent. Concentrations up to 0,3 % were found. According to the content of Zn in rocks we distinguished 3 zones (fig. 3). The first zone with content of Zn of 0.1 to 0,3 % is situated in close proximity to the

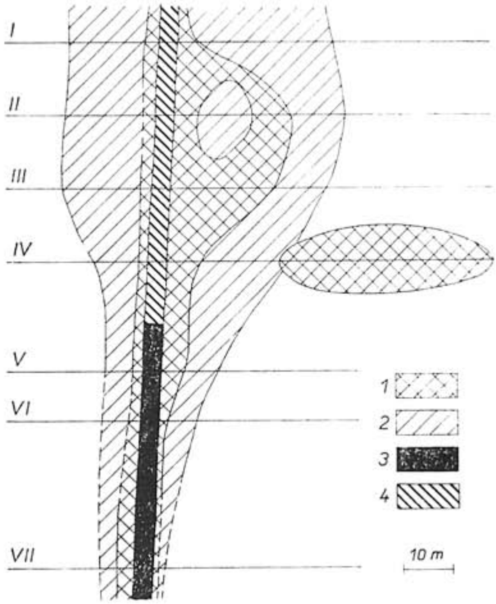


Fig. 2. Sketch of the primary aureole of Pb at the deposit in vertical direction (sketches in fig. 2 and 6 were made from profiles across several veins at the deposit). These profiles were ranged one under another according to vertical zonation of ore filling in veins (Pb-Zn-Cu) what represents the depth of about 600 m. The measure in fig. 2 to 6 is related to distance from the veins (along X axis). 1 — Representation of Pb 0,05 to 0,1 %; 2 — Representation of Pb 0,01 to 0,05 %; 3 — Pb-Zn zone of the ore filling of the veins; 4 — Cu zone of the ore filling of the veins; I — Ferdinand Adit across the Terézia Vein; II — 1th horizon of the Maxmilián Pit across the Terézia Vein; III — 5th horizon of the Maxmilián Pit across the Terézia Vein; IV — 12th horizon of the Maxmilián Pit across the Terézia Vein; V — 12th horizon of the Michal Pit, cross adit across the underlying Bieber Vein; VI — Bakaly Cross Adit through the Rozália Vein; VII — cross adit in the 12th horizon near the Rozália Vein.

veins with the ore filling of the Pb-Zn zone, where underlying the veins its maximum width is 16 m and in rock overlying them it is 5 m only. In deeper parts of the deposit this zone is tapering out. Rocks with the content of Zn of 0,05 to 0,1 % were found in the 12th horizon of the Maxmilian Pit in the section of 20 to 31 m in rock underlying the Terézia Vein, where the pyroxenic andesite is penetrated with dikes of dacite. The third zone with the content of Zn of 0,01 to 0,05 % is the widest one. Near the veins with the ore filling of the Pb-Zn zone it is 10 to 65 m wide and in deeper parts of the deposit near veins of the zone of Cu its width diminishes to 3 to 6 metres. In greater distance from the veins (behind the mentioned zones) the content of Zn in rocks varies from 0,004 to 0,01 %.

Barium forms the widest zones with higher content in rocks. According to the content of Ba in rocks we distinguished two zones near the veins (fig. 4). The first zone with content of Ba of 0.5 to 1 % is situated in close proximity of the veins with ore filling belonging to Pb-Zn zone up to the maximum distance of 5 m from the veins. Higher content of Ba (0,5—1 %) was found in the Bakaly Cross Adit in rock underlying the Rozália Vein at a distance of 13 to 100 m. Relation of this anomaly to the course of the ore veins should be also studied further on. The second zone with the content of Ba 0,1 to 0,5 % is distinct around the veins of the middle and upper zone of Pb-Zn, where it reaches maximum width of 38 m. In deeper parts, i. e. in the zone of Cu it is suddenly thinning away and gradually disappears. After the mentioned zones at a greater distance from the veins the content of Ba in rocks varies from 0,03 to 0,1 %. In its qualities it is even near to potassium and substitutes it isomorphously. In places of enrichment in potassium in the process of rock alternation near the veins also the content of Ba increased in rocks (fig. 4 and 5).

Copper is found in rocks in thousandths and hundredths of per cent. The highest concetrations of Cu were found to be up to 0,03 %. According to the content in rocks

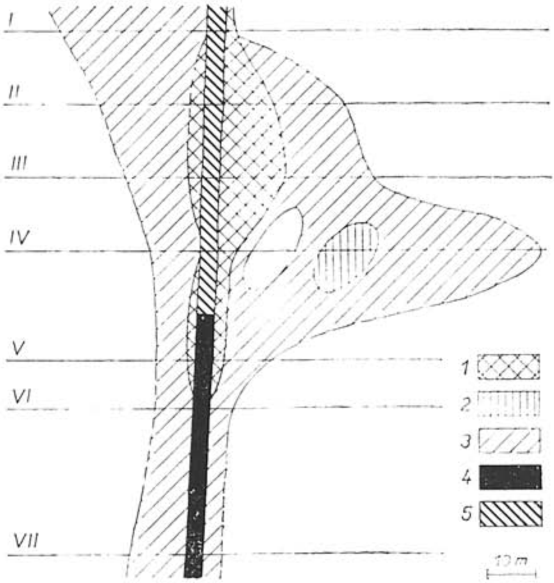


Fig. 3. Sketch of primary aureole of Zn at deposit in vertical direction. 1 — Representation of Zn 0,01 to 0,3 %; 2 — Representation of Zn 0,05 to 0,1 %; 3 — Representation of Zn 0,01—0,05 %; 4 — Pb-Zn zone of the ore filling of the veins; 5 — Cu zone of the ore filling of the veins; I — Ferdinand Pit across the Terézia Vein; II — 1st horizon of the Maxmilián Pit across the Terézia Vein; III — 5th horizon of the Maxmilián Pit across the Terézia Vein; IV — 12th horizon of the Maxmilián Pit across the Terézia Vein; V — 12th horizon of the Michal Pit, cross adit through the underlying Bieber Vein; VI — Bakaly Cross Adit through the Rozália Vein; VII — Cross Adit in the 12th horizon near the Rozália Vein.

we distinguished two zones (fig. 6). The first zone with content of Cu of 0,01 to 0,03 % is situated around the veins with ore filling corresponding to Cu zone, being 2 to 10 m wide there. In higher parts of the deposit (near the veins of the Pb-Zn zone) it is gradually tapering out. The second zone with the content of Cu of 0,006 to 0,01 % is situated near the veins with the filling of the Pb-Zn zone, its maximum width is 6 m. In deeper parts of the deposit it seems as if wedged out and it is substituted by the zone with higher content of Cu in rocks (fig. 6). In the 12th horizon of the Maxmilian Pit in rock underlying the Terézia Vein in 20 to 30 m the content of Cu is higher (0.01—0.03 %) in places where the dykes of dacite are crossing the pyroxenic andesite. At greater distance from the veins the content of Cu in rocks varies within the range of 0.002 to 0.006 %.

Silver is the rocks almost regularly dispersed in ten thousandths of per cent and shows only slight indications of zonation regarding to the course of ore veins. In places more distant from the veins the content of Ag varies in rocks from 0.0001 to 0,0004 % and in proximity of the veins it shows the tendency to higher content from 0.0005 to 0.0008 %.

Cobalt is almost equably dispersed in the amount of 0,0007 to 0,002 %. In proximity of the ore veins no essential changes are evident in the content of Co in rocks. In rocks Co probably displays isomorphous substituion with Fe^{+2}, the ion radius of which is very near to it.

Nickel does not show essential changes in concentration in rocks regarding to the course of ore veins. In rocks it is scattered in concentration of 0,0006 to 0,003 %. Ni is probably bound to chlorites, in which it may display isomorphous substitution with Mg.

Lithium is dispersed in rocks in concentration from 0,006 to 0,026 %. In rocks it does not show dependence on the course of ore veins. It does not form own minerals, but probably displays isomorphous substitution with Al in plagioklases.

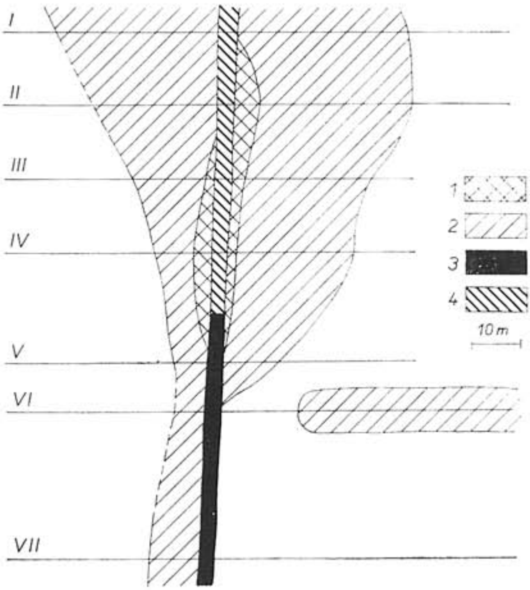


Fig. 4. Sketch of primary aureole of Ba at the deposit in vertical direction. 1 — Representation of Ba 0,5 to 1 %; 2 — Representation of Ba 0.1 to 0,5 %; 3 — Pb-Zn zone of the ore filling of the veins; 4 — Cu zone of the ore filling of the veins; I — Ferdinand Pit across the Terézia Vein; II — 1st horizon of the Maxmilián Pit across the Terézia Vein; III — 5th horizon of the Maxmilián Pit across the Terézia Vein; IV — 12th horizon of the Maxmilián Pit across the Terézia Vein; V — 12th horizon of the Michal Pit, across adit through the underlying Bieber Vein; VI — Bakaly Cross Adit through the Rozália Vein; VII — Cross adit in the 12th horizon near the Rozália Vein.

Strontium is present in rocks prevailingly in hundredths and to a small extent in tenths of per cent only. Near the veins it shows slight tendency to change of the content in rocks. Diminishing of Sr content near the veins is connected with intense breaking of plagioklases and carrying away of Ca from rocks. In places near the veins its representation is getting a little higher where more intense formation of carbonates was taking place with rock alteration.

Vanadium is prevailingly dispersed in hundredths of per cent. Its concentration in rocks varies from 0.007 to 0.50 %. Near the veins it shows only slight tendency to diminishing its content in rocks. In proximity of the veins a decrease in iron from is evident, with which vanadium probably displays isomorphous substitution in rocks.

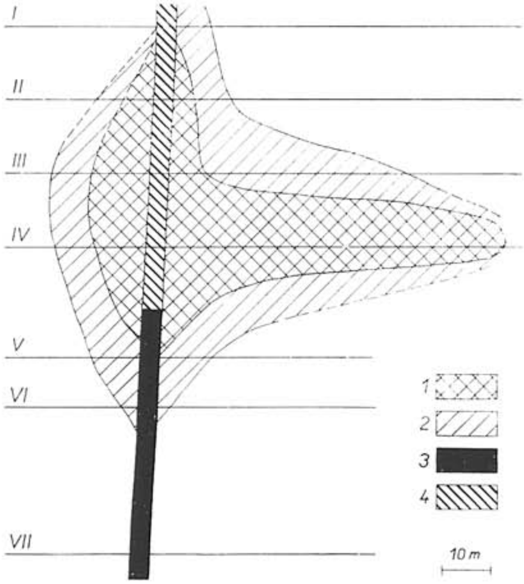
Gallium is regularly dispersed in rocks and does not show greater changes in the content regarding to the course of ore veins. In the studied rocks the content of Ga mostly varies between 0.0005 and 0.001 %. In rocks it probably displays isomorphous substitution with Al.

Zirconium is present in rocks in thousandths and hundredths of per cent. In accessory amounts in rocks it forms its own mineral zircon. Its content in rocks does not show conspicuous changes with regard to the course of ore veins, but is probably irregularly dispersed in them in the values of 0.004 to 0.020 %.

Mercury is almost regularly dispersed in rocks in amounts of 0,00001 to 0.0001 %. Near the veins it does not show increase or decrease in its content in rocks.

Molybdenum is rarely present and has not been found in most samples. Its presence was only recorded in some samples in amounts of 0.002—0.009 %. Sn was also found only scarcely in highest amounts up to 0.001 %.

From the group of rare earths we traced Sc and La. Sc is represented in rocks in thousandths of per cent within the range of 0.002—0.006 %. Sc does not show dependence on the course of ore veins. La has not been found in the studied rocks in any sample.



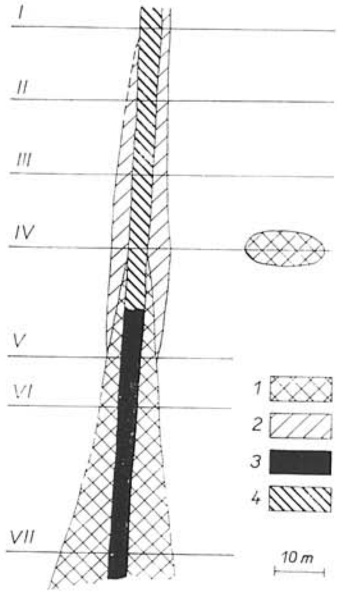


Fig. 5. Sketch of primary aureole of potassium at the deposit in vertical direction. 1 — Representation of K_2O more than 6 %; 2 — Representation of K_2O more than 3,5 %; 3 — Pb-Zn zone of the ore filling of the veins; 4 — Cu zone of the ore filling of the veins; I — Ferdinand Pit across the Terézia Vein; II — 1st horizon of the Maxmilián Pit across the Terézia Vein; III — 5th horizon of the Maxmilián Pit across the Terézia Vein; IV — 12th horizon of the Maxmilián Pit across the Terézia Vein; V — 12th horizon of the Michal Pit, cross adit through the underlying Bieber Vein; VI — Bakaly Cross Adit through the Rozália Vein; VII — Cross Adit in the 12th horizon near the Rozália Vein.

Fig. 6. Sketch of primary aureole of Cu at the deposit in vertical direction. 1 — Representation of Cu 0.01 to 0.03 %; 2 — Representation of Cu 0,006 to 0,01 %; 3 — Pb-Zn zone of the ore filling of the veins; 4 — Cu zone of the ore filling of the veins; I — Ferdinand Pit across the Terézia Vein; II — 1st horizon of the Maxmilián Pit across the Terézia Vein; III — 5th horizon of the Maxmilián Pit across the Terézia Vein; IV — 12th horizon of the Maxmilián Pit across the Terézia Vein; V — 12th horizon of the Michal Pit, cross adit through the underlying Bieber Vein; VI — Bakaly Cross Adit through the Rozália Vein; VII — Cross adit in the 12th horizon near the Rozália Vein.

II. Secondary Aureoles

Besides primary aureoles of dispersion of elements around the veins of B. Štiavnica we also studied distribution of some elements in secondary aureoles of dispersion in the marginal parts of the ore district of Banská Štiavnica by the method of ground metallometry.

The microchemism of neovolcanic rocks is very diverse and almost each effusion or intrusive body shows different quantitative representation of microelements, the content of which also changed with post-volcanic alterations. Frequent alternations of rocks is therefore very unfavourable for the study of secondary aureoles of these elements, which are found in greater amounts in rocks. It is therefore advantageous together with the principal elements to trace also some accompanying elements which frequently provide for better results in the study of secondary aureoles of dispersion.

In the area of the ore district of Banská Štiavnica we traced secondary aureoles of dispersion of Ag, Pb, Zn, Cu and in some areas of Au. From these elements Pb, Zn and Cu are commonly found in neovolcanic rocks. Ag only rarely in more acid and altered types of rocks.

Secondary aureoles of dispersion of elements in neovolcanic areas of Slovakia were studied by J. Novotný (1958), Fr. Fiala, Z. Pácal (1959), M. Böhmer, E. Mecháček (1966), J. Slávik (1967) and others.

In the area of the ore district of Banská Štiavnica the first works about the study of secondary aureoles of dispersion are by J. Našinec, J. Pokorný (1967) and J. Novotný (1958) from the northern margin of the ore field. J. Novotný (1958) considers Ag, Pb, Zn, partly also Mo as the most suitable elements, Cu as not suitable. St. Polák (1963), who laid main emphasis on tracing of Cu came to negative results.

Statistic Treatment of Results

The semiquantitative spectral analyses were evaluated by aid of SPD scale and treated statistically. For the traced elements distribution curves were made (fig. 7, 8, 9, 10). On the basis of them we determined phone contents.

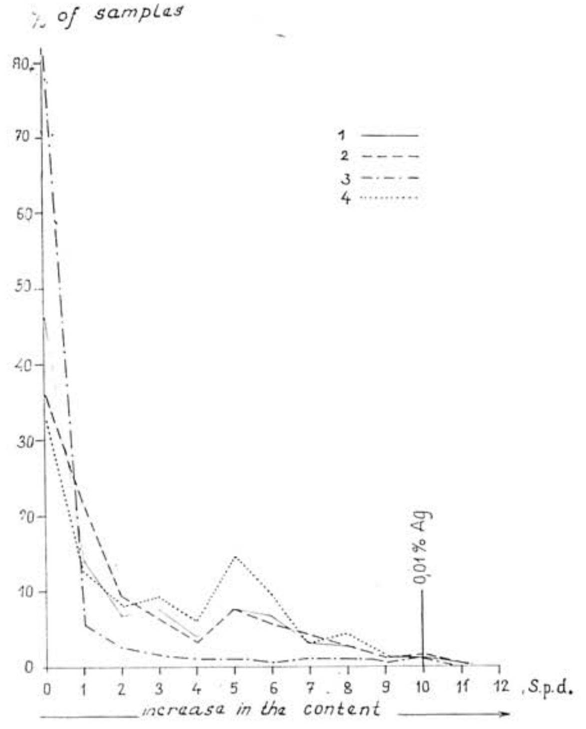


Fig. 7. Distribution curves of Ag in deluvial weathering products (spectral analyses according to SPD scale). 10th degree of SPD scale = 0,01 % Ag. 1 — Marginal parts of the ore district of Banská Štiavnica on the whole (on the basis of 2 900 analyses); 2 — Area in northern continuation of the Grüner Vein (900 samples); 3 — Area in northern termination of the veins of Banská Štiavnica (1200 samples); 4 — Area of northern continuation of the veins, south of the communities of Žakyľ and Podhorie (900 samples).

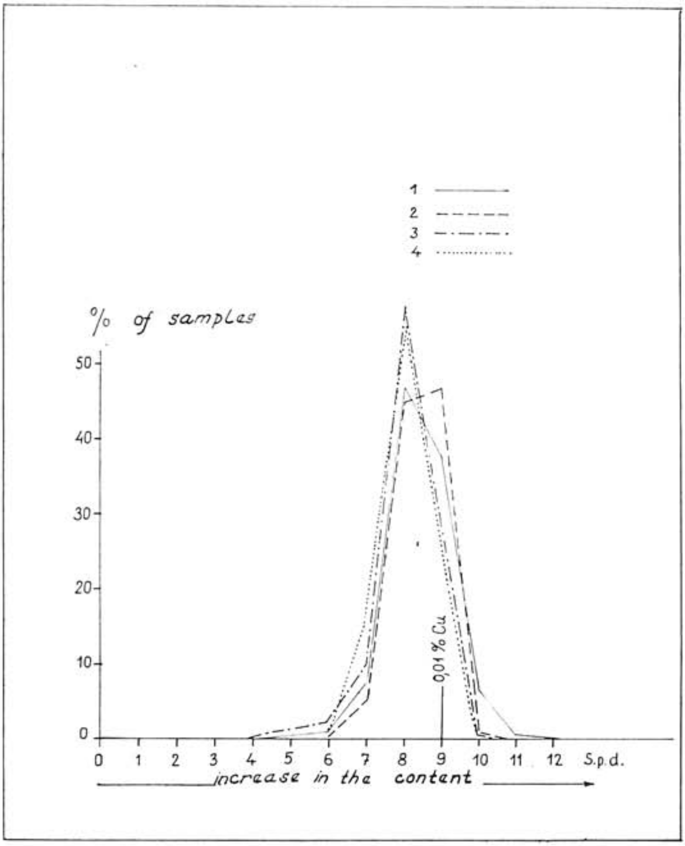


Fig. 8. Distribution curves of Cu in deluvial weathering products (spectral analyses according to SPD scale). 9-th degree of SPD scale = 0,01 % Cu. 1 — Marginal parts of the ore district of Banská Štiavnica on the whole (on the basis of 2900 analyses); 2 — Area in northern continuation of the Grüner Vein (900 samples); 3 — Area in the northern termination of the veins of Banská Štiavnica (1200 samples); 4 — Area of the northern continuation of the veins, south of the communities of Žakyľ and Podhorie (900 samples).

Pb, Zn and Cu, found in small concentrations in neovolcanic rocks display a character of distribution curve different from Ag, which is only rarely found in surrounding rocks.

Distribution of Ag (fig. 7) in samples treated by ground metallometry is lognormal with distinct positive asymmetry. On the distribution curve of Ag are two maxima. The first maximum is in the area of zero values of Ag, to which 35—80 % of samples is corresponding, 46 % on an average. The number of samples with content of Ag is higher in the southern profiles and towards the northern margin of the ore field its number decreases. The second maximum, little distinct, is on the 5—6th degree of SPD scale. It is only distinct on profiles striking across the supposed course of the structure of the Grüner Vein. It is no more found in the profiles south of the communites of Žákyľ and Podhorie.

Distribution curve of Cu (fig. 8) displays the character of normal dispersion, common at elements well migrating in the zone of hypergenesis. The contents of Cu mostly vary around the value of 0,01 %. The distribution curve already shows Cu not to form greater anomalies.

The distribution of Pb (fig. 9) in metallometeric samples is lognormal with relatively wide dispersion of contents. The maximum is at contents somewhat lower than 0,02 % Pb.

On the distribution curve of Zn (fig. 10) there are two maxima, one at the 1-st degree of SPD scale. The first maximum may be caused by small sensibility of spectral analysis.

Results of Study of Secondary Aureoles of Ag, Pb, Zn, Cu

We obtained the best results in the study of secondary aureoles of Ag. Ag and Au are in the veins of Banská Štiavnica mainly concentrated in the upper parts of the veins, as also confirmed by the study of primary aureoles in some types of rocks near the veins.

Ag in secondary aureoles attains the values of about 0,01 % and forms very distinct surfaces with anomalous and over phone contents, at which zonal distribution of Ag is frequently observable. The highest contents of Ag are found in the centre of the zones and content decreases towards the margin. This is the case in the area of the continuation of the Grüner Vein, the veins of Banská Belá, the Terézia and Bieber veins. As the principal veins have a series of apophyses, together with wide anomalous zones also narrow ones are found. As an example we mention distribution of Ag in the deluvium of the area of supposed northern continuation of the Grüner Vein (fig. 11, 12, 13) and the profile through the veins of Banská Belá (table 3).

The Grüner Vein was in the upper parts relatively rich in Ag and therefore we paid attention to distribution of this element. The map of Ag isolines (fig. 11) shows considerably high contents of Ag in northern continuation of the Grüner Vein. Ag forms an almost continuous plane with anormalous and over phone contents, the direction of which agrees with the general strike of the Grüner Vein. This plane is only interrupted in the area of the small massif of basalt at the Kalvária Hill formed by basalt. Planes with over phone contents have zonal structure. In the centre the contents of Ag are around 0,01 % and towards the margins in the deluvium they decrease quite regularly to phone ones. The anomalous plane of Ag is most distinct north-east of the Kalvária Hill. It is 200—400 m wide and in the centre of the zone in several cases contents of about 0,01 % Ag were found. In fig. 12 there is distribution of Ag, Pb, Cu in one profile NE of the Kalvária Hill, on which zonal distribution of Ag around the supposed course the structure of the Grüner Vein is to be seen. Less distinct is the anomaly SW of the Kalvária Hill. It is 100—200 m wide, but the contents are lower by 2—3 degrees of SPD scale. The detail of one profile is in fig. 13.

The contents of Ag around the small massif of basalt of the Kalvária Hill are essentially lower and attain the 5th degree of SPD scale as maximum. The deluvium above the basalt is almost without Ag and only rarely contents of 2—3 degrees of SPD scale were found.

A very wide zone with over phone and anomalous contents of Ag is situated north of Banská Belá in the section of the veins Baumgarten, Goldfährer and Juraj (fig. 15).

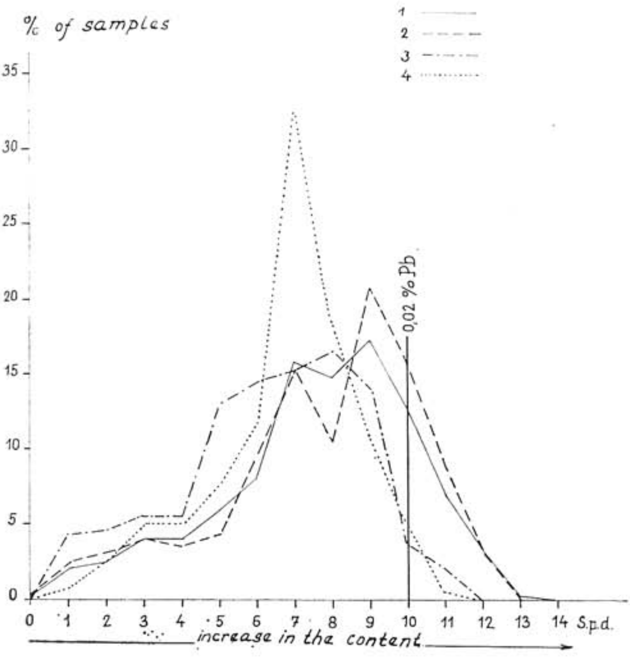


Fig. 9. Distribution curves of Pb in deluvial weathering products (spectral analyses according to SPD scale). 10th degree of the SPD scale = 0,02 % Pb. 1 — Marginal parts of the ore district of Banská Štiavnica on the whole (on the basis of 2900 analyses); 2 — Area in northern continuation of the Grüner Vein (900 samples); 3 — Area in the northern termination of the veins of Banská Štiavnica (1200 samples); 4 — Area of the northern continuation of the veins, south of the communities of Žakyľ and Podhorie (900 samples).

Table 3. Phone, over phone and anomalous contents of Ag, Pb and Cu in the deluvium of marginal parts of the veins of Banská Štiavnica

	Phone contents	Over phone contents	Anomalous contents
Ag	0—1	more than 1,5	more than 5
Pb	9	10—11	more than 11,5
Zn	5,5	more than 5,5	more than 7,5
Cu	8	more than 8,5	more than 10,5

The values are in SPD scale. The 10th degree of SPD scale = 0,01 % Ag, 0,002 % Pb. The 9th degree of SPD scale = 0,01 % of Cu, the 6th degree of SPD scale = 0,02 % of Zn.

This zone is 300 m wide and in the centre of the anomalous zone Ag contents are more than the 7th degree of SPD scale, in places they are also 0,01 %. Towards the marginal zone Ag contents decrease.

The study of distribution of Pb in secondary aureoles did not provide for as favourable results as the study of distribution of Ag. Pb is found in neovolcanic rocks in the values up to 30 ppm what frequently causes origin of false anomalies, especially, in places, where the inclination of the slope is suddenly lowering, in saddles etc. In sections of supposed continuation of vein structures Pb is frequently found in the deluvium in anomalous contents, but the planes are less continuous and Pb contents change rapidly also at short distances. In areas of vein structures Pb contents vary in limits more than

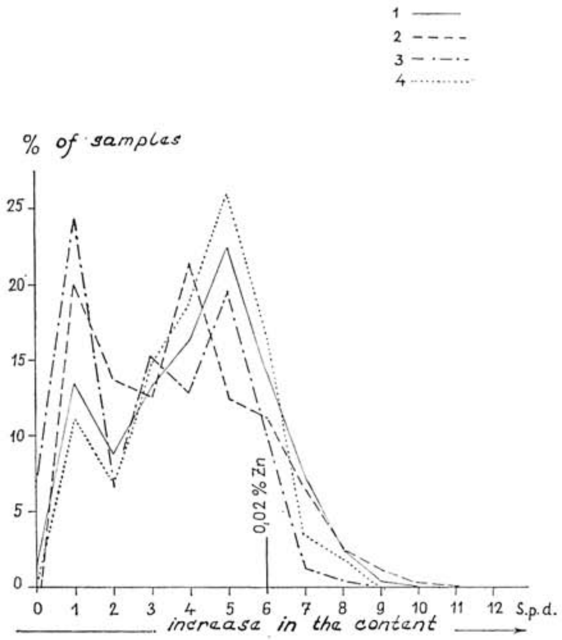


Fig. 10. Distribution curves of Zn in deluvial weathering products (spectral analyses according to SPD scale). 6th degree of SPD scale = 0,02 % Zn. 1 — Marginal parts of the ore districts of Banská Štiavnica on the whole (2900 analyses); 2 — Area in northern continuation of the Grüner Vein (900 samples); 3 — Area of northern termination of the vein of Banská Štiavnica (1200 samples); 4 — Area of northern continuation of the veins of Banská Štiavnica, south of the communities of Žakyľ and Podhorie (900 samples).

0,02 % by 1—3 degrees of SPD scale and are frequently correlable with anomalous contents of Ag, e. g. in the area of the Grüner Vein (fig. 12, 13), of the continuation of the structure of the Terézia Vein. Correlation between Ag and Pb is understandable because Ag is found in galenites from the veins of Banská Štiavnica.

As an example of distribution of Pb in the deluvium of the area of northern continuation of the vein of Banská Štiavnica we mention the map of isoconcentrations in the deluvium north of the Grüner Vein (fig. 14) and the profile across the veins north of Banská Belá (fig. 15). In the area of continuation of the structure of the Grüner Vein Pb forms a plane with over phone contents of SW—NE direction, interrupted in the area of the Kalvária Hill, similarly as that of Ag. The zone with over phone and anomalous contents of Pb is, however, not very continuous, being as wide as 150—350 m. The contents of Pb decrease from the centre of anomalous zones towards the margin, transversely to the supposed course of the vein. As fig. 12 and 13 show Pb is little distinct. In the area of vein structures north of Banská Belá Pb contents are not higher (fig. 15).

Over phone contents of Pb are frequently found also outside the supposed course of vein structures, which, however, are not correlable with the higher contents of Ag, but frequently with higher contents of Zn.

Negative results were obtained in the study of secondary aureoles of Zn. Zn is commonly found in neovolcanic rocks and only rarely forms more distinct planes with over phone or anomalous contents in deluvial weathering products. Distribution of Zn in deluvial weathering products is very irregular and its contents are varying also at short distances.

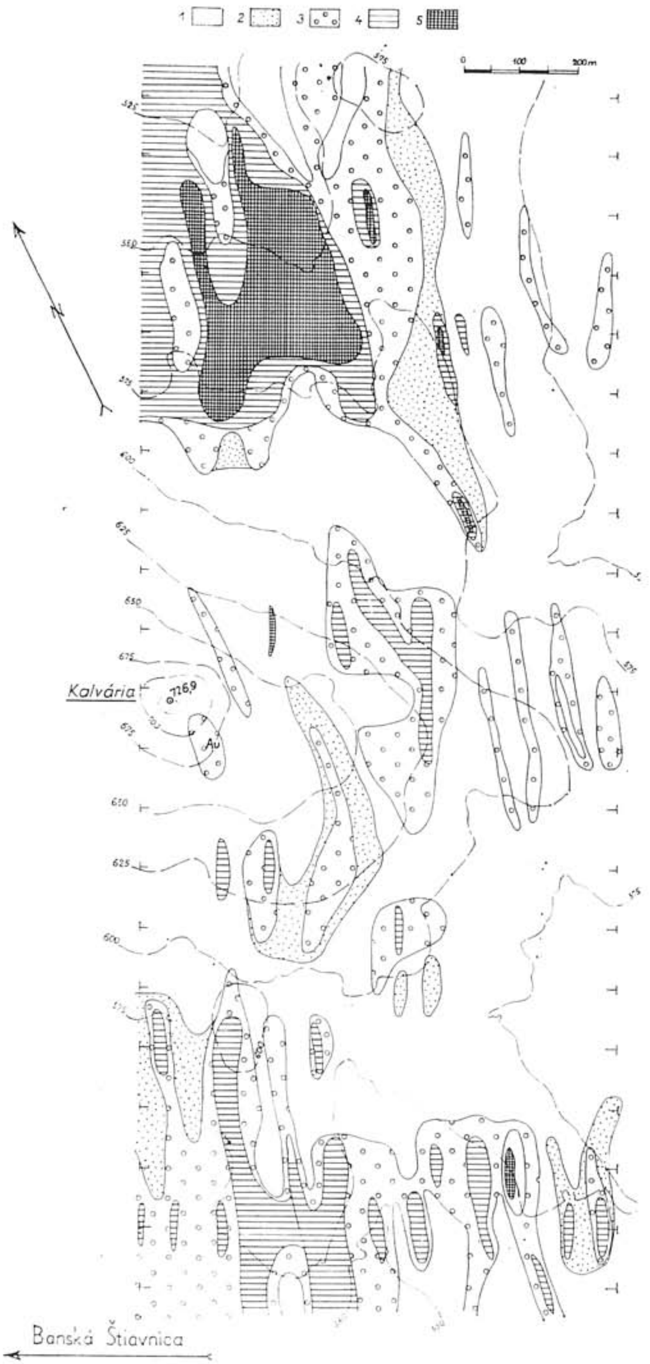


Fig. 11. Map of isoconcentrations of Ag in deluvial weathering products in northern continuation of the Grüner Vein. Underlying rocks are amphibole-biotitic andesite, in the area of the Kalvária Hill (72 6,9) there are basalts. 1 — Contents of Ag about one phone and under phone; 2 — Contents of Ag over phone; 4—5 — Anomalous contents of Ag (Phone, overphone and anomalous contents see tab. 3).

Zn contents are more dependent upon the underlying rocks than on the course of vein structures. In areas of supposed course of vein structures Zn only rarely forms planes with anomalous or over phone contents and anomalous contents of Zn are only rarely correlable with higher contents of Ag of Pb. Anomalous contents of Zn are correlable best with anomalous ones of Ag in the area of supposed northern continuation of the structure of the Terézia Vein. In other studied areas, in areas of supposed

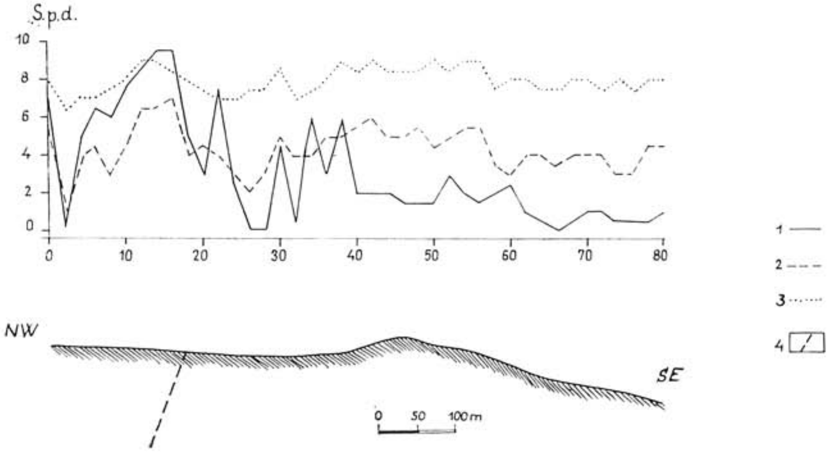


Fig. 12. Distribution of Ag, Pb and Cu in deluvial weathering products on one profile SE of the Kalvária Hill, in the area of supposed course of the structure of the Grüner Vein. Underlying rocks are amphibole-biotitic andesites. 1 — Curve of contents of Ag; 2 — Curve of contents of Pb; 3 — Curve of contents of Cu; 4 — Supposed course of the structure of the Grüner Vein.

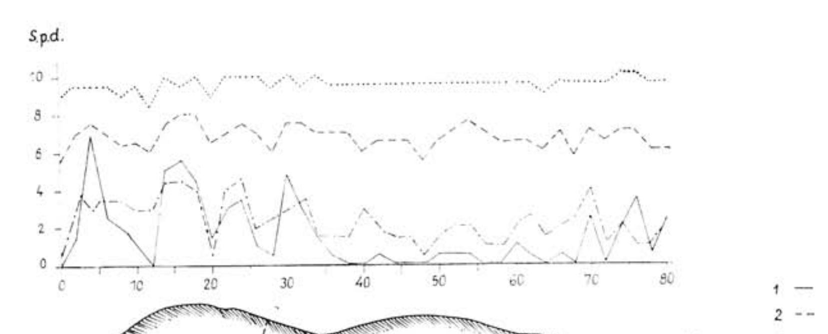


Fig. 13. Distribution of Ag, Pb, Zn and Cu in deluvial weathering products on the profile SW of the Kalvária Hill, in the area of supposed structure of the Grüner Vein. Underlying rocks are amphibole-biotitic andesites. 1 — Curve of contents of Ag; 2 — Curve of contents of Pb; 3 — Curve of contents of Zn; 4 — Curve of contents of Cu; 5 — Supposed course of the Grüner Vein.

course of the vein structures over phone or anomalous contents of Zn are found rarely only.

Over phone contents of Zn are found in the area of the small massif of the Kalvária Hill that probably intersects the structure of the Grüner Vein. Higher contents of Zn are correlated with no element. Higher content of Zn is caused by its content in primary basalt of the Kalvária Hill in contrast to amphibole-biotitic andesites.

Over phone contents are frequently found in saddles, as it was observed e. g. in the area of southern continuation of the vein structures of Banská Štiavnica, south of the community of Štefultov and of Štiavnické Bane, also in the deluvium originated on amphibolic, biotitic andesites of III. eruption phase.

As the study of secondary aureoles showed, contents of Zn are largely dependent upon the character of underlying rocks and the morphology of the country and consequently this element is not suitable to be applied for localization of vein structures in neovolcanic structures.

Fig. 12 and 13 show Zn not to form any anomaly in the area of continuation of the structure of the Grüner Vein.

Distribution of Cu in deluvial waste is very regular. The contents of Cu in 90 % of cases vary in the values of about one phone and do not form any anomaly. Samples with over phone contents of Cu are rarely found and almost in the same places where are also anomalous contents of Pb, Zn or Ag.

Conclusion

In the area of the ore district of Banská Štiavnica with polymetallic ore mineralization we studied distribution of trace elements in the complex of neovolcanic rocks. We found out the character of primary and secondary aureoles of dispersion of trace elements in rocks surrounding the veins in subsurface parts of the deposit and on the surface in places of supposed course of ore structures.

We studied p r i m a r y a u r e o l e s in pyroxenic andesite, dacite and quartz diorite. In the ore district of Banská Štiavnica the complex of neovolcanic rocks was penetrated with post-volcanic solutions. With the effect of these solutions on the rocks changes in petrographic and chemical composition of principal rock-forming constituents were taking place. This information is mentioned in the works by J. F o r g á č (1966, 1967). On the basis of the study of the content of trace elements we may state that changes in representation of trace elements were taking place in rocks in proximity of the channelways, along which hydrothermal solutions were ascending. We divided the trace elements into 3 groups according to representation in rocks surrounding the channelways.

In the first group are Pb, Zn, Cu, Ba, K. These elements display higher content in rocks in proximity of the ore veins (figs. 1—5), Pb, Zn, Ba show more distinct zonation around the veins, the ore filling of which belongs to Pb-Zn zone. In these places the primary aureoles of dispersion of Pb, Zn, Ba are several times wider than around the veins, the ore filling of which corresponds to Cu zone. Potassium in rocks behaved in the process of post-volcanic changes similarly as Pb, Zn and Ba. Potassium in these anomalies is prevailingly bound to adular. Primary aureoles with higher content of Cu in rocks are lying in proximity of the veins, where the ore filling belongs to Cu zone. Cu forms much narrower primary aureoles than Pb, Zn, Ba and K.

Anomalous increase in Pb, Zn, Cu, K is also evident in the 12th horizon of the Maxmilian Pit in rock underlying the Terézia Vein in places, where the dacite dyke

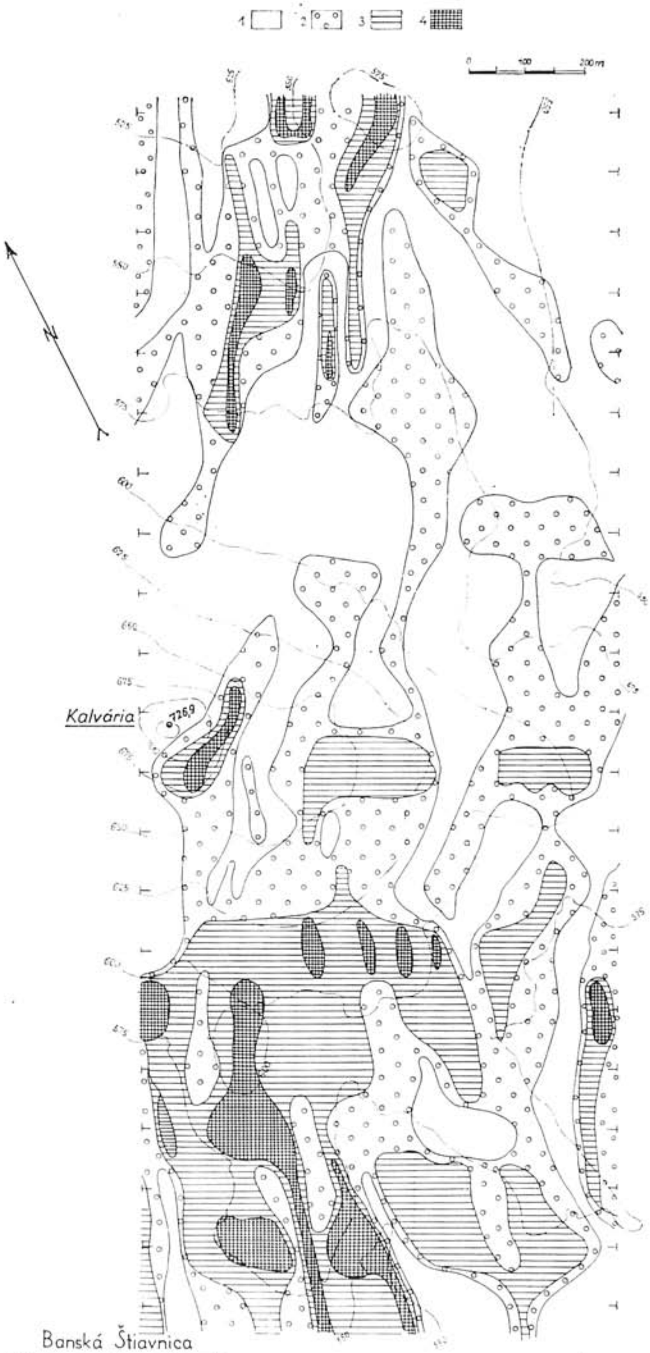


Fig. 14. Map of isoconcentrations of Pb in deluvial weathering products in northern continuation of the Grüner Vein. Underlying rocks are amphibole-biotitic andesites, in the area of the Kalvária Hill (726,9 there are basalts). 1 —Under phone contents of Pb; 2 — Contents of Pb about one phone; 3 — Over phone contents of Pb; 4 — Anomalous contents of Pb. (Phone, over phone and anomalous contents see in tab. 3.)

pierces pyroxenic andesite. This phenomenon shows ore-bearing solutions to have partly used the same ascending ways as dacites.

In the second group are the elements Ag and Sr showing only slight indications of changes of the content in rocks near the veins. At Ag increasing tendency of its content in rocks is evident, mainly in the upper parts of the deposit. Strontium shows dependence on the content of calcium in rocks. With decrease in the content of Ca in rocks in proximity of the veins also the content of Sr decreases and vice versa.

In the third group Co, Ni, Li, Ga, V, Zr, Hg, Mo, Sc are included. These elements do not show any conspicuous changes in rocks near the veins.

All the study of primary aureoles of dispersion of elements shows most distinct aureoles in neovolcanic complexes of rocks to be formed by the elements of Pb, Zn, Cu, Ba and K. The width of these aureoles is changing in vertical direction at the deposit, what is dependent on the character of ore filling of the veins.

S e c o n d a r y a u r e o l e s o f d i s p e r s i o n o f e l e m e n t s were studied in deluvial weathering products of the volcanic complex in places of supposed course of continuation of ore bearing structure. We traced the elements: Ag, Pb, Zn and Cu.

Ag in deluvial weathering products forms distinct anomalies, in which it in places attains values of about 0.01 %. Very distinct anomalies vere found in the area, where we may suppose northern continuation of the structure of the Grüner Vein, of the structure of the Terézia Vein and the veins of Banská Belá, in the area north of Antol and partly in the deluvium above the dykes of dacites. Pb forms secondary aureoles less distinct than those of Ag. A distinct anomaly of Pb was found in prolongation of the Grüner and Terezia Veins, where Pb is correlable with Ag. Anomalies of Zn are less distinct and correlable with other elements in several cases only. Anomalies of Zn are correlable with Ag south-west of the Kalvária Hill and in the area of the Terézia Vein. The contents of Cu are in the studied area about one phone and do not form any anomaly.

Anomalous zones in secondary aureoles of dispersion frequently show zonal distribution of the contents of elements. In the centre of anomalous zones the contents of elements are the highest ones and towards the margins their content decreases. We

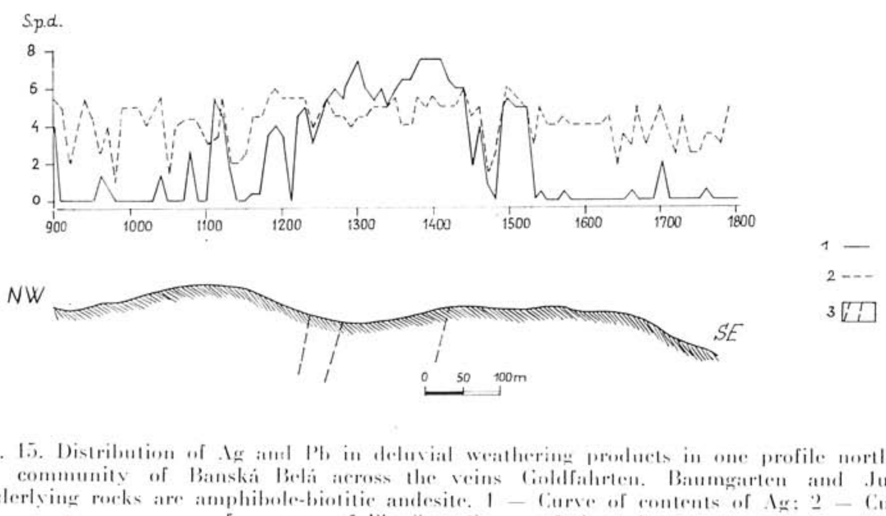


Fig. 15. Distribution of Ag and Pb in deluvial weathering products in one profile north of the community of Banská Belá across the veins Goldfahrten, Baumgarten and Juraj. Underlying rocks are amphibole-biotitic andesite. 1 — Curve of contents of Ag; 2 — Curve of contents of Pb; 3 — Course of the veins.

observed this phenomenon at Ag and Pb, mainly near continuation of the structure of the Grüner and Terézia Veins.

The study of secondary aureoles of dispersion of Ag, Pb and Zn shows vein structures of the ore district of Banská Štiavnica to continue also in the north of their known course as far as the area of Žakyľ and Podhorie. The structure of the Grüner Vein continues for about 2 km in NNE direction.

The results of study secondary aureoles of dispersion in the area of Banská Štiavnica we consider as positive. The best results were obtained in the study of distribution of Ag and Pb, less accurate at Zn and negative ones at Cu.

The character of distribution of elements is different at primary and secondary aureoles of dispersion. This is mainly in connection with zonal distribution of elements in vertical direction at the deposit.

Primary aureoles of Cu are getting wider in deeper parts and in uppermost parts of the veins they are very narrow or not observable at all. To this distribution of Cu in vertical direction at the deposit also corresponds the character of secondary aureoles of dispersion in deluvial weathering products. As Cu was only very little evident in subsurface parts of deposits in the studied area and migrates well there, it does not form any anomalies in secondary aureoles and its distribution is very regular.

Primary aureoles of Pb and Zn have a character opposite to Cu. They are wider in subsurface parts of the veins and in deeper parts are getting narrower. Pb and Zn therefore form more distinct secondary aureoles of dispersion. They are more distinct at Pb, which migrates bad in the zone of hypergenesis and less distinct at Zn, well migrating in the zone of hypergenesis.

Ag does not form more distinct primary aureoles of dispersion in upper parts of the veins and is of particular position. With regard to that Ag is concentrated in upper parts of the veins and is mostly found in values less than 0.0001 %, it however forms distinct secondary aureoles of dispersion.

Translated by J. Pevný.

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Review by B. Cambel.