MILOSLAV BÖHMER, ERNEST MECHÁČEK*

SOME RESULTS OF GEOCHEMICAL DRAINAGE SURVEY IN NEOVOLCANITES OF KREMNICKÉ HORY MOUNTAINS

(Textfig. 1—4)

A b s t r a c t: In this work partial results from regional geochemical prospection in northern part of Middle Slovakian Neovolcanites are submitted. The method of geochemical investigation of secondary mineralogical and lithochemical aureolas in Recent sediments of stream system has been applied. The methods of work are described there and a characteristic of secondary aureolas in drainage sediments of stream system from ore district and peripheral regions is there submitted.

Introduction

The ore deposits of precious metals, polymetals and cinnabar in neovolcanites of Middle Slovakia in most cases have an ancient history. The deposit of gold ore in Kremnica situated in observed region had its first record about well developed and organized mining already from the year 1385. In spite of this long lasting mining activity represent the ore fields of neovolcanites of Middle Slovakia with very extensive and intensive hydrothermal zones from the standpoint of prospection also in our times a perspective territory. This is valid particularly if we consider that old digging and mining works were founded only on basis of visual prospecting methods where as guides for prospection served mainly surface outcrops of ore veins, their mechanical trains in eluvium, deluvium and aluvium and zones of altered volcanites. We suppose that modern prospecting methods based on geochemical and geophysical principles connected with the solving of the details of geological structure mainly from structural and volcanologic point of view can also in these territories exploited since long time ago find new objects of deposits for detailed investigation.

In the first stage of works it is necessary to apply prospecting methods enabling to explore greater territories with sufficient sensibility and minuteness of details. From this standpoint also with our works carried out in connection with compiling of geological and deposit maps 1 : 50 000 we have applicated the method of geochemical drainage survey. The mentioned method has its advantage in its universality. When we combine by geochemical investigation of this type panning of heavy minerals with spectrochemical investigation of fine grained, predominantly clayey fraction of stream sediments we are enabled to find out mineralogical secondary trains formed by resistent minerals from the deposits and rocks on the one hand and lithochemical trains formed by mobile elements absorbed predominantly in clay minerals of stream sediments on the other hand. With regard to the character of ore mineralization we have traced in our case mineralogical as also lithochemical secondary trains of dispersion. An advantageous supplement to this method is also the tracing of hydrochemical aureolas in water of streams and springs. The hydrogeochemical investigation of waters we have not applied in our case. The principles of prospecting on basis of geochemical drainage surveys have been described e. g. in the works of V. I. K r a s n i k o v (1959), H. E. H a w k e s, J. S. W e b b (1962), to whose works we keep also in questions of terminology.

The aim of the carried out works is to judge the perspectivity of northern part of neovolcanites in Middle Slovakia mainly from the point of view of their ore contents

* Doc. Ing. M. B ö h m e r, CSc., Prom. geol. E. M e c h á č e k, Departement of Mineral Row-Materials and Geochemistry, Faculty of Natural Sciences, Komenský University, Bratislava, Jiráskova 12.

on the one hand and to judge applicability of this method under existing geological and natural conditions on the other hand. Since our geochemical prospecting works have not yet been finished the submitted results don't include all the problems connected with regional geochemical prospecting works in observed region.

Brief Charakteristic of Natural Conditions

The original volcanic relief has undergone to strong destruction. In the eastern part of the mountains Flochová (1318 m) dominates, to the south from which a series of ridges extends in an altitude of 900—1100 m. In western part of the mountains Vysoká (909 m) dominates. In the centre of the mountains a fauld zone in the direction from north to south extends causing a variegated geological structure of this part of the mountains. A considerable ramified stream system covers regularly the territory having mostly deep erosion valleys. The mountains are bordered by foothills of hilly country character. The average annual temperature is 5 °C. The annual average of precipitations in lowlands is 800—900 mm, in top position exceeds 1200 mm. The predominating type of soil is the forest brownearth. Except the central part the mountains are very wooded.

Brief Charakteristic of Geologie and Ore Deposits

The essential part of Kremnické hory mountains is formed by Miocene volcanites of IInd andesite phase (M. K u t h a n 1962). They are various varieties of pyroxenic, less of amphibole-pyroxenic andesites and their pyroclastic rocks deposited on the base of volcanic complex prevailingly in water environment. The products of the younger, the IIIth andesite phase are amphibole-biotitic andesites succeeded by Sarmatian rhyolites and rhyodacites attributed to IIIth rhyolite phase. We place to this period also the rise of secondary potash trachytes (Fr. F i a l a 1961, M. B ö h m e r 1961). The products of the both younger volcanic phases occur on fault lines of N—S direction intersecting the centre of the mountains. On the same dislocation zone also Pliocene basaltoid andesites occur (Fig. 1).

The hydrothermal mineralization in Kremnické hory mountains is concentrated in two ore fields. In the centre of the mountains is situated the Kremnica ore field formed by more vein systems connected prevailingly with faults in the direction NNE-SSW. The ore veins, genetically connected with hypabyssal equivalents of Sarmatian rhyolites are formed prevailingly by quartzose supply periods with small quantities of pyrite and arsenopyrite and accessorie quantities of Zn-, Pb-, Cu-, Ag-, Mo-sulphides and sulphosalts. The electrum occurs mostly submicroscopic but some ore systems are characterized by visible electrum. The younger supply periods are formed by dolomite and chalcedony accompanied sometimes by minable concentrations of antimonite. The ore mineralization is accompanied by very extensive hydrothermal alteration of andesites. A detailed description of deposit relations of the Kremnica ore field is given in the works of M. B ö h m e r (1961, 1964, 1965). A further ore field on the eastern end of Kremnické hory mountains is composed of abandoned deposits Malachov, Tajov, Králiky with typical telethermal mineralisation represented mainly by cinnabar, realger and orpiment.

The Geochemical Drainage Survey

The investigation of heavy mineral concentrates of secondary mineralogical trains.

The surveing of heavy mineral concentrates has been carried out by Z. P e t ř e k

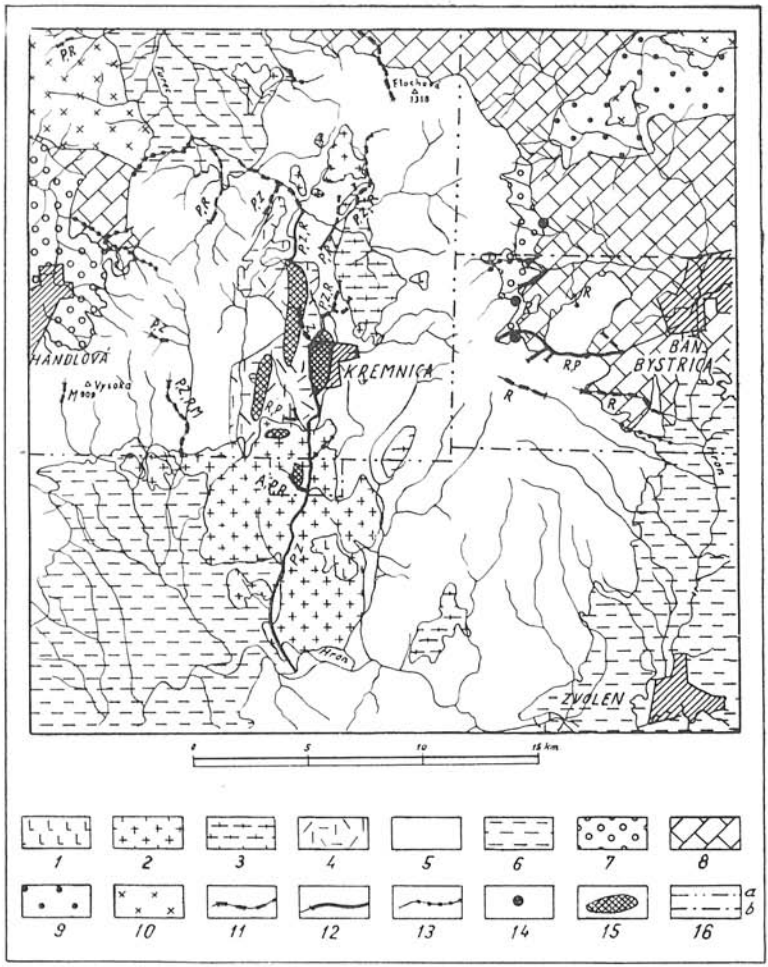

Fig. 1. Schema of secondary mechanical trains of ore minerals in the stream sediments of Kremnické hory mountains. Pliocene: 1 — basaltoid andesites; Miocene: 2 — rhyolites, rhyodacites and their pyroclastic rocks, IIIth rhyolite phase; 3 — amphibole-biotitic andesites of IIIth andesite phase; 4 — pyroxenic andesites of IInd andesite phase, predominantly propylitized and kaolinized; 5 — pyroxenic andesites and their pyroclastic rocks; 6 — Miocene sediments; 7 — Paleogene; 8 — Mesozoic; 9 — Permian; 10 — Crystalline; 11 — isolated grains of ore minerals in heavy mineral concentrates; P — pyrite; R — cinnabar; Z — gold; M — closer undetermined ore minerals; 12 — numerous grains of ore minerals in heavy mineral concentrates; 13 — from ore minerals only pyrite was ascertained in heavy mineral concentrates; 14 — location of mercury, realgar, orpiment deposits Malachov, Tajov, Králiky; 15 — location of vein system of Kremnica ore field — Au, Ag, Sb; 16a — territory, on which has been carried out investigation of heavy mineral concentrates and metallometric survey of fine grained fraction of the stream sediments is being accomplished; 16b — territory, on which heavy mineral concentrates survey has been carried out.

(1960) and Š. H o m z a (1962). By 439 samples total has been sampled 314 km of the stream system and that the whole map sheet Kremnica 1 : 50 000 and the surrounding of the Malachov deposit (Fig. 1). The weight of panned material was 6—10 kg. In laboratory investigation has been applied the current method of dividing of heavy mineral concentrates in fractions according to grain size and physical qualities. The investigation of heavy mineral concentrates has brought data about the extension of ore mineralization in space and additional knowledges about the extension of some accessoric minerals in neovolcanic rocks.

On fig. 1 are schematically shown the sections of streams, in which were found ore minerals of hydrothermal genesis in heavy mineral concentrates. In the region of Kremnica the ore mineralization in heavy concentrates is represonted by minerals pyrite, gold, antimonite, cinnabar, pure mercury. In the ore field of Malachov we have found high-grade mineralogical trains of cinnabar and pyrite, sporadically also pure mercury. From received results the following conclusions may be drawn: the ore minerals in heavy mineral concentrates mark clear the position of both ore-fields, although in the environs of Kremnica a part of the stream system could not be sampled due to the adjustement of the river bed. The both ore fields are separated by a „barren zone" corresponding to ridges of an altitude 900—1100 m extending from the Flochová mountain to the south. The wide extent of found trains of ore-minerals is remarkable reaching far behind the limits of known parts of Kremnica ore field laterally but mainly in the direction N—S, i. e. in the direction of regional fault system. Such investigation of heavy mineral concentrates enables to imagine the actual extent of hydrothermal activity. Considering the significance of secondary mineralogical aureolas in Kremnica ore field it is necessary to reason also the change of mineralization with depth. The mineralization of tectonic zones weakens quickly upwards to younger members of andesite complex and therefore a zone mineralized intensively in depth, exposed by erosion only in upper parts, where only a weak indicatory mineralisation exists, shows itself very weakly in heavy mineral trains. For this reason it is necessary to pay attention also to feebler symptoms of ore associations in heavy mineral concentrates. The part of anomal sections of streams in the ore fields of Kremnica and Malachov correspond to new so far unknown indications of ores.

Except mentioned ore-minerals heavy fraction from neovolcanites was composed of following association of rock-forming minerals: magnetite, hypersthene, augite, amphibolite, biotite, olivine, epidote, garnet, apatite, zircon, rutile, anatase, disthene, spinel, sillimanite, andalusite, turmalin, feldspars, quartz.

The character of the association of rock-forming and accessoric minerals in heavy fraction completes considerably mainly our knowledges on distribution of accessoric minerals in particular regions and types of volcanites.

The presence of rhyolites in heavy fraction manifests expressively by higher contents of zircon. For the river-basin of Turiec river the presence of spinel in heavy fraction is typical, which is a rare accessory in some types of volcanites. For the eastern part of Kremnické hory mountains are characteristic relatively high contents of garnets, although in this territory have not been described till now garnet andesites.

Stream Sediment Survey

The samples for this kind of investigation are taken from Recent sediments of the streams in the distance of 50 to 100 m. As samples fine grained sediments with higher contents of clay minerals are taken. The weight of the sample is 100—150 g; the

material is taken from two to three places distant one from another 2—5 m. After drying up the samples undergo sieve analysis and with spectral analysis the fraction under 0,3 mm is investigated. At first we have used semiquantitative spectral analysis, which has not been fully suitable for this purpose. Now we use quantitative spectral analysis carried out by J. Jarkovský in a method adjusted by him. Gride spectrograph PGS-2, generator BIG-100, phase shift 1.5 with frequency 10 Hz/sec., exposition 25 sec. are used, than on the same place photographic plates with the frequency 50 Hz/sec., exposition 30 sec. Both expositions with 5 Amp. Exposition on blau-hart plates. The sensitivity for particular elements is: Cu, Ag — 1 ppm, Pb, Mo, Sn — 10 ppm, B — 20 ppm, Hg — 50 ppm, Sb, W, Zn — 100—150 ppm, As — 1000 ppm. Reproducibility ± 10—25 % relative.

By the choice of elements for quantitative spectral analysis we proceded from spectral analysis of volcanites in the region of Kremnica (Fr. Fiala 1961), of ores from the Kremnica deposit (M. Böhmer 1963) and carried out semiquantitative spectral anaiyses of clayey fraction from the drainage sediments. We took into account also the association of elements Sn-Mo-Bi ascertained in Kremnica ore district by Fr. Fiala.

In quantitative way we have investigated following elements:

Ag — which is found besides Au as the main ore component on veins of the Kremnica ore field. In rocks Ag has not been found out except som acid types of volcanites.

Cu, Pb, Zn are present as subordinate to trace elements on veins of the Kremnica ore field. They are found also in volcanic rocks, especially more basic rocks, having values to 10 ppm (Cu, Pb), 200 ppm (Zn). In acid rocks the contents of these elements is somewhat lower.

Sn, W, Mo — these elements have been found out only rarely on the veins of Kremnica. In rocks these elements have not been found except Sn, which appears seldom in trace quantities in acid differentiates of volcanic rocks.

Sb, Hg, As — Sb-mineralization is known directly in Kremnica ore field. Hg and As in peripheral regions. In volcanic rocks of Kremnica region these elements have not been found out.

B — is common in volcanic rocks in Kremnica region reaching values 10—100 ppm and takes part in hydrothermal alternations.

The background contents in fine fraction of drainage sediments samples have been calculated from the whole region because the investigated territory is formed prevailingly by andesitic rocks having all very similar chemical composition mainly the contents of the trace elements. The background contents of investigated elements are: Ag — 1 ppm, Cu — 36 ppm, Pb — 40 ppm, Zn — 230 ppm, B — 30 ppm. The remaining elements have lower sensibility with quantitative spectral analysis and these contents we take already for anomal: Mo — 10 ppm, Sn — 10 ppm, Hg — 50 ppm, Sb, W — 100 ppm, As — 1000 ppm.

We take for anomal contents the double background contents at Cu, Pb, Zn, B and Ag and the limit of sensibility of quantitative spectral analysis at Mo, Hg, Sb, W, Sn.

We have investigated the chemical homogenity of sampled material of the fraction under 0,3 by 9 analyses of the same sample. The relative standard deviation has these values: B — 4.5 %, Cu — 8 %, Pb — 18 %, Zn — 75 %. At other quantitatively observed elements we do not mention relative standard deviation because these elements have not been found in analyzed sample. It follows that the homogenity of sample is relatively high enabling taking of a fraction for the purpose of quantitatives spectral analysis from material under 0.3 mm without any homogenisation what simplifies the work.

Geochemical Characteristic of the Section from the Ore Region

To verify the applicability of this method in the prospection of mineralized zones we have valuated one geochemical section of the stream intersecting the principal vein system of Kremnica (right tributary of Rudnica flowing under the Revolta). In this case we have analyzed the samples by semiquantitative spectral analysis. The fine grained fraction of stream sediment had almost in the whole section over background contents of Ag (10—100 ppm), Cu (10—100 ppm), Zn (above 100 ppm). The contents of B and Pb reached approximately to the background. By 10 % of samples Sn was found out. W, Mo, As, Sb and Hg were not established. If we compare this section with sections lying outside of ore zones we see that Ag is mostly missing in these sections and also the contents of the other elements reach only the values about background.

Geochemical Characteristic of Sections from the Region Lying Outside of Ore Field

Drainage areas of most streams are formed by various types of andesites and less also by rhyolites. A part of the territory is formed also by pyroclastic rocks with andesitic and to a less degree with rhyolitic material.

The contents of elements followed quantitatively in particular sections are monotonous enough. This is valid first of all for Cu (Fig. 2, 3, 4). On the other hand Pb and Zn but mainly Zn have very variable contents also on short distance. These elements are common in rocks and in this way we may also explain the considerable variability of their contents on short distance because a part of these elements is found still in undecomposed dark minerals (amphibole, pyroxene). A part of Cu, Pb and of Zn mainly with contents over background must be ascribed to manifestation of ore mineralization. The remaining estimated elements are not found in rocks and appear always together in a larger section of streams.

The influence of volcanic rocks forming the slopes as also the various porosity of rocks have no greater influence on the contents of elements in samples of stream sediments (Fig. 2). Dislocation structures have much more influence on the contents of elements in fine fraction of the stream sediments. From investigations carried out hitherto results that near every tectonic line appear higher contents of Cu (Fig. 4) or of Cu, Pb, Zn (Fig. 3) and in some cases also of Ag and Sn (Fig. 3, 4). The raise of the contents of these elements is very expressive and that to twice and five times as the background contents. Boron does not show any expressive dependence on tectonic lines except one case (the valley of Slaská) where around a tectonic line and to a distance of 200 m from it the contents of boron are three to eight times higher as the background. The other quantitatively estimated elements on this tectonic line have only background contents.

Im some cases we can compare the results of sampling of heavy mineral concentrates with the results of quantitative spectral analysis of fine grained fraction of stream sediments. In the section of Čierna dolinka valley by the surveying of heavy mineral concentrates have been found out: pyrite, cinnabar, gold, pure mercury in very low concentration. This mineralogical aureole derives from faults in N—S direction on which a rhyodacite body appears. The aureole is created only by indicatory mineralization of upper parts of volcanic complex, which were eroded by a stream. On dislocations lying more in the depth have been ascertained very intensive alterations of andesites. Semiquantitative spectral analysis showed in this stream Cu, Zn, Pb and also Hg.

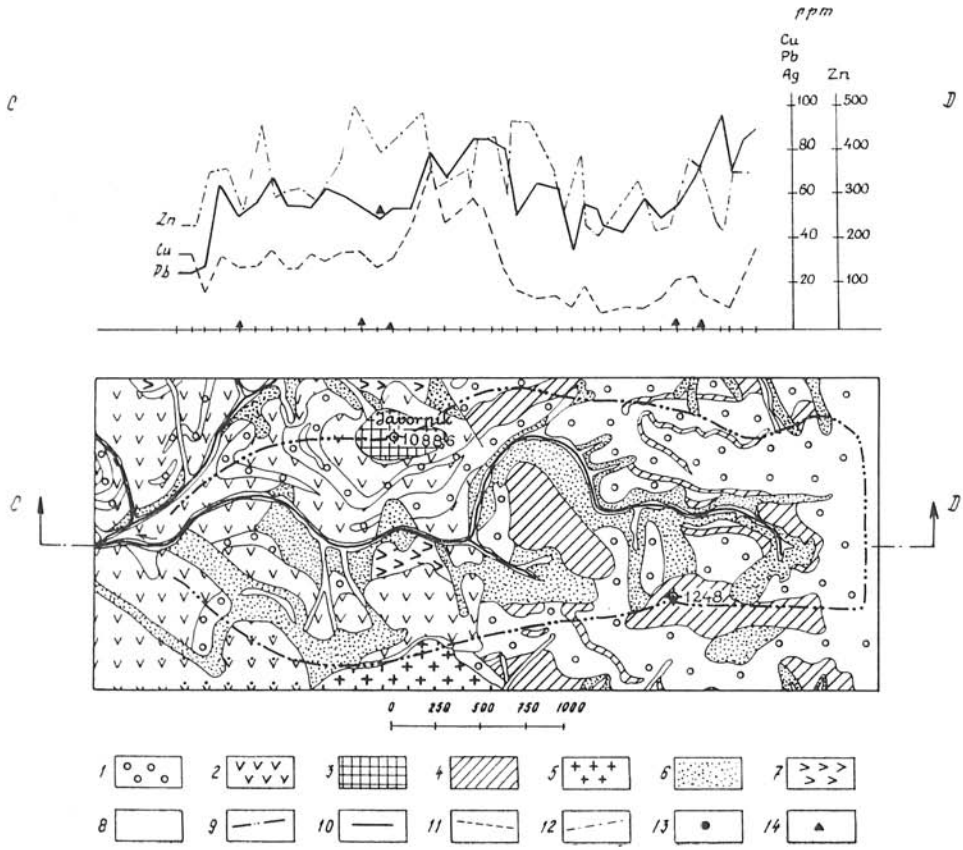

Fig. 2. Geochemical section of fine grained fraction of stream sediments. The valley south from Smrečník. Geological relations according to the geological map of Fr. Fiala (1961). 1 — agglomerate tuffs of pyroxenic and amphibole-pyroxenic andesites, pyroxenic andesites with accessory amphibole and biotite, and top andesites; 2 — pyroxenic andesites with accessory amphibole and biotite; 3 — amphibole-biotitic andesites; 4 — top pyroxenic andesites; 5 — rhyolites; 6 — slope loams and debris; 7 — block sheets; 8 — Aluvium; 9 — drainage area; 10 — Pb contents in ppm; 11 — Cu contents in ppm; 12 — Zn contents in ppm; 13 — Sn contents in ppm; 14 — Ag contents in ppm.

Consequently mineralogical as also lithochemical aureole has been produced in stream sediments there.

The anomal contents of elements in the region of Kremnica ore field seldom attains larger extent and usually anomal contents are found in several following samples. There is e. g. over background contents of Ag together with Zn on the lenght around 150 m (Fig. 2). On fig. 4 we observe considerable extension of anomalies as a result of a cross dislocation intersecting the valley. To hitherto ascertained most important anomalies the anomalies between the mountains Flochová and Smrečník belong. In the Turček valley an expressive Ag and Mo anomaly has been found out in a section of 300 m, more to the south in Bystrica valley, south from the Javorník an expressive anomaly of Pb, Cu and also a weak anomaly of Ag were discovered. Also in Bystrica valley an Ag

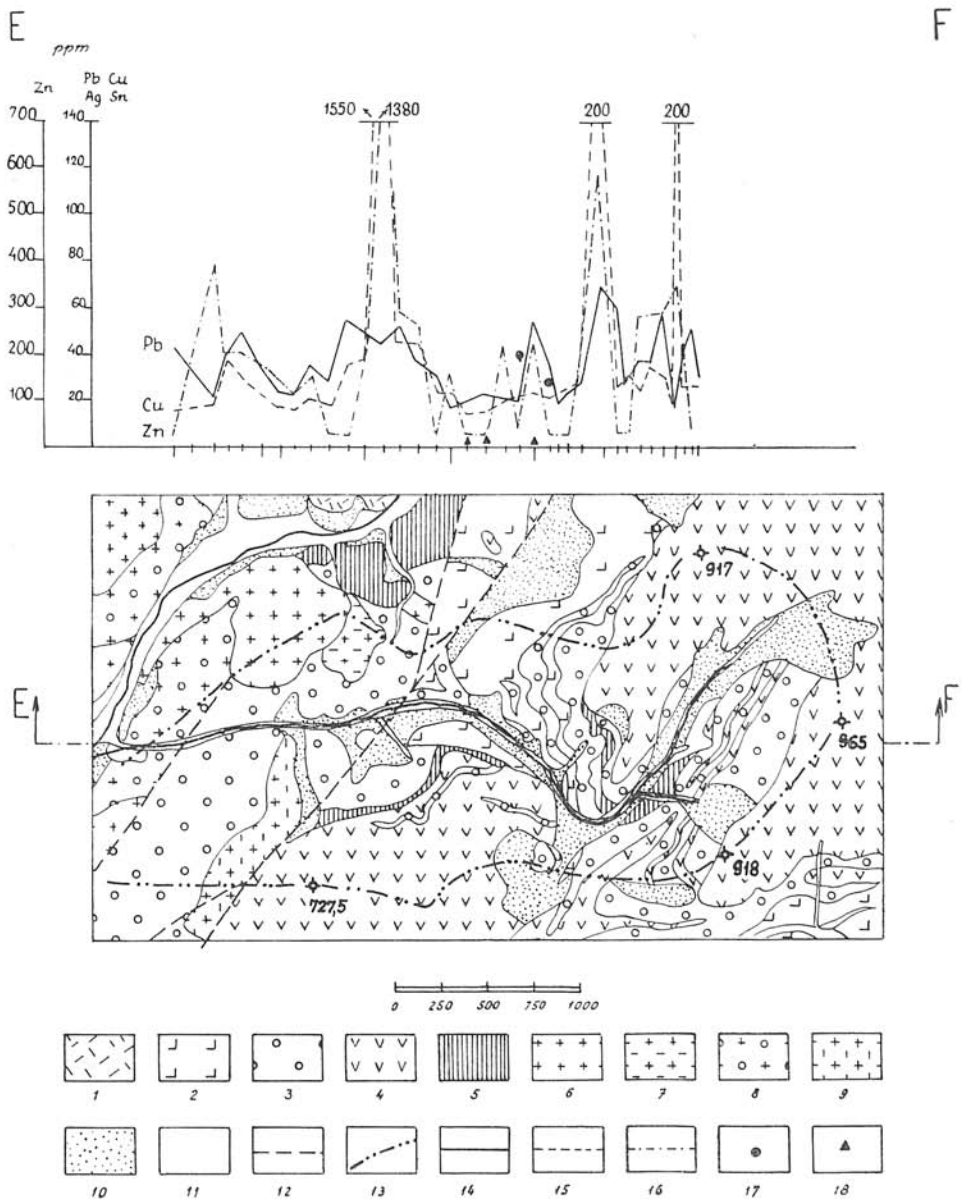

Fig. 3. Geochemical section of fine grained fraction of stream sediments. The valley south from Nevoľné. Geological relations according to the geological map of Fr. Fiala. 1 — pyroxenic aphanitic andesites, partly propylitized; 2 — pyroxenic andesites with amphibole; 3 — agglomerate tuffs of pyroxenic and amphibole-pyroxenic andesites, pyroxenic andesites with accessory amphibole and biotite, top andesites and rhyolites; 4 — pyroxenic andesites with accessory amphibole and biotite; 5 — amphibole-pyroxenic andesite with basaltic amphibole; 6 — rhyolites; 7 — pumiceous rhyolite; 8 — sanidine rhyolites; 9 — felsitic rhyolites; 10 — slope loams and debris; 11 — Aluvium; 12 — tectonic lines; 13 — drainage area; 14 — Pb contents; 15 — Cu contents in ppm; 16 — Zn contents in ppm; 17 — Sn contents in ppm; 18 — Ag contents in ppm.

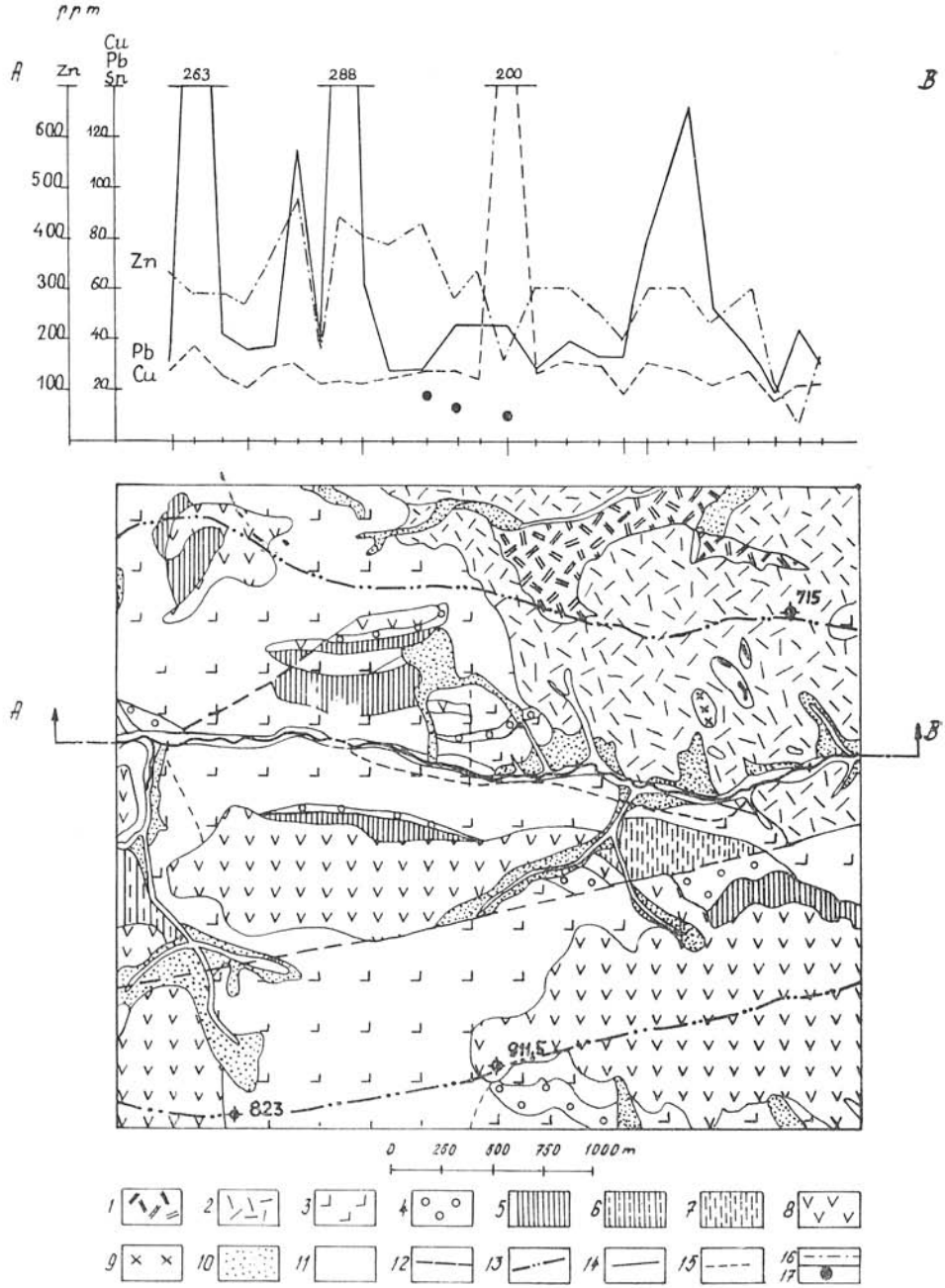

Fig. 4. Geochemical section of fine grained fraction of stream sediments. The valley between Kopernica and Lúčky. Geological relations according to the map of Fr. Fiala (1961). 1 — propylitized and kaolinized pyroxenic andesites; 2 — aphanitic partly propylitized pyroxenic andesites; 3 — pyroxenic andesites with amphibole; 4 — agglomerate tuffs of pyroxenic and amphibole-pyroxenic andesites, pyroxenic andesites with accessory amphibole and biotite and top andesites; 5 — amphibole-pyroxenic andesite with basaltic amphibole; 6 — amphibole-pyroxenic andesite with green amphibole; 7 — amphibole-pyroxenic andesite with biotite; 8 — pyroxenic andesites with accessory amphibole and biotite; 9 — metasomatic microgranite from Kopernica; 10 — slope loams and debris; 11 — Aluvium; 12 — tectonic lines; 13 — drainage area; 14 — Pb contents in ppm; 15 — Cu contents in ppm; 16 — Zn contents in ppm; 17 — Sn contents in ppm.

anomaly is found. The mentioned zone of the ridge in the south from the Flochová mountain is characterized by lithochemical aureoles without present mineralogical ore aureoles.

The correlation among elements is not very expressive. Close correlation has been observed mostly between Cu and Pb or Cu and Zn.

Conclusions

On basis of existing results from geochemical drainage survey carried out on Recent sediments of stream system in the neovolcanites of Kremnické hory mountains we came to conclusion that this method was suitable as the first, the regional stage of geochemical exploration under given physical-geographical and geological conditions. The method is sensible enough to discover both secondary mineralogical and lithochemical trains also in territories, where no evidence of endogenous mineralisation could be ascertained by geological survey. The first-rate task is the evaluation and geological interpretation of each anomal section from the standpoint of prospection. No less important is the knowledge that the data received by regional geochemical investigation of stream sediments to a significant degree complete the knowledges on metallogenetic and geological relation of observed territory. The exact recognization of spatial extension of secondary mineralogical and lithochemical aureolas enables to create a more perfect regional idea on primary aureoles of mineralization and so on actual spatial extent of hydrothermal activity providing significant aid in defining of ore fields and metallogenetic districts of higher order. As follows from mentioned material are found the anomal sections of Recent stream sediments in dependence on dislocation structures. They define in reliable way the course of particular dislocations (Fig. 3, 4) or of whole fault systems (Fig. 1). This is a significant aid to the solving the tectonics of the territory because in monotonous volcanic sequences the surveying of fault structures is very difficult.

Translated by J. Pevný.

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