Environment Studies to Determine the Impacts of Re-opening Banksá Štiavnica-Hodruša Ore District in Czechoslovakia

By DUŠAN CABALA[1] and MARIÁN SKAVINIAK

Geologický prieskum, n.p. Spišská Nová Ves, Czechoslovakia

ABSTRACT

Some better perspectives applying to the exploitation and dressing of polymetallic ores in the Banská Štiavnica-Hodruša Ore District are supposed to be achieved after a successful investigation and proving there the existence of deep-seated mineralization as well as due to increasing demand for non-ferrous metals and consequently to higher market prices of those recently noticed. With respect to the present situation in mining and to the further technical development as well, a several times higher exploitation may be in this region expected, especially in the deeper-seated parts of the deposit. When solving the tasks of a complex economic exploitation over the whole region, considerable attention is paid to regional relations and impact studies (due to expected exploitation and ore dressing) but also to very difficult problems of dewatering (drainage problems). It will be first of all necessary to find there an equilibrium between the consequences resulting from the renaissance of mining industry and environmental requests undispensable for the city of Banská Štiavnica and the other neighbouring towns in the vicinity of mining plants.

INTRODUCTION

The Štiavnické vrchy Mts. have been subject to mining since the ancient times (B.C.). An increased activity in non-ferrous ore exploitation in the XIIth century has been there especially noticed when passing from the surface to underground mining. Due to favourable conditions, a large settlement was there formed - Banská Štiavnica city with neighbourhood.
Banská Štiavnica had chartered town privilege and dispensed one of the oldest authorizations for undertaking there mining activity. Mining brought about many intricate problems (e.g. the question of power sources necessary for ore transporting from underground) which were successfully solved in the XVIIth century and resulted in considerable in-

creasing of exploitation for this time. Under these circumstances a unique conception of water management has been developed there including water utilization in ore crushing and dressing as well. Water hoisting engines e.g. are considered as the top mining equipments applied that time. Increased output level brought about, however, an increased accumulation of groundwater in the underground workings. For this reason, a network of drainage tunnels has been driven, from among which the 16,5 km long and more than 100 years old Voznica Drainage Tunnel is still in operation. In 1735, a Mining Academy being later on of university level has been in the city of Banská Štiavnica established.
In the second half of the XIXth century, apparent decreasing in mining activity took there place. In sense of the Czechoslovak Government decision, an intense development is in the Štiavnica Mines since 1977 carried out in order to estimate possible mining in the subject area.

GEOLOGICAL AND MINING CONDITIONS

Mineralizations present in the area of Banská Štiavnica and Hodruša and in the close vicinity of those are referred to the so-called Banská Štiavnica-Hodruša Ore District.
From geological point of view, it is a polygene stratovolcano including its lower and upper stratovolcanic structure and covering an area of about 1000 km^2. On the basis of data obtained from the studies realized until now, the subject stratovolcano was of multistage development having passed through caldera stage and later on, it has been to a great extent covered by the products of explosive and effusive activity. In the termination stage of volcanic activity, horst structure origination took place in the caldera area. Due to an intense and long-lasting denudation of the upper parts of the horst, the lower levels of volcanic structure and somewhere the Pre-Tertiary Basement (NW part) have been exposed (see Fig. 1). The evolution of the intricate Štiavnica Stratovolcano is associated in space and time with extensive metallogenesis of Pb-Zn-Cu-Au-Ag ores, with lesser amounts of some Fe ones.
The Banská Štiavnica-Hodruša Ore Field covers the surroundings of the cities mentioned chiefly and is there represented by the main vein structure formed by the Terézia, Bieber and Špitáler Veins. Their known length in strike is about 7-8 km the width being 2,5 to 3,0 km. They join the Rozália Vein on W, the Grüner Vein on E and on NE the Banská Belá Veins.
From mining point of view, the Banská Štiavnica Ore Field is developed up to the Drainage Level, i.e. up to a depth of about 500 m below the surface. Prognoses of ore reserves and geological survey works are projected up to 1300 m. The predominant part of reserves reaching the Drainage Level has been worked-out already and the remaining ones are important in the central part of the ore field only. Mineralization is of polymetallic nature (see Fig. 2). In addition to Cu, Pb, Zn and less amount of Au and Ag, presence of Bi and W has been there also noticed.

FIG.1 GEOLOGICAL SCHEME OF THE BANSKÁ ŠTIAVNICA-HODRUŠA ORE DISTRICT (ACCORDING TO KONEČNÝ-BURIAN 1984)

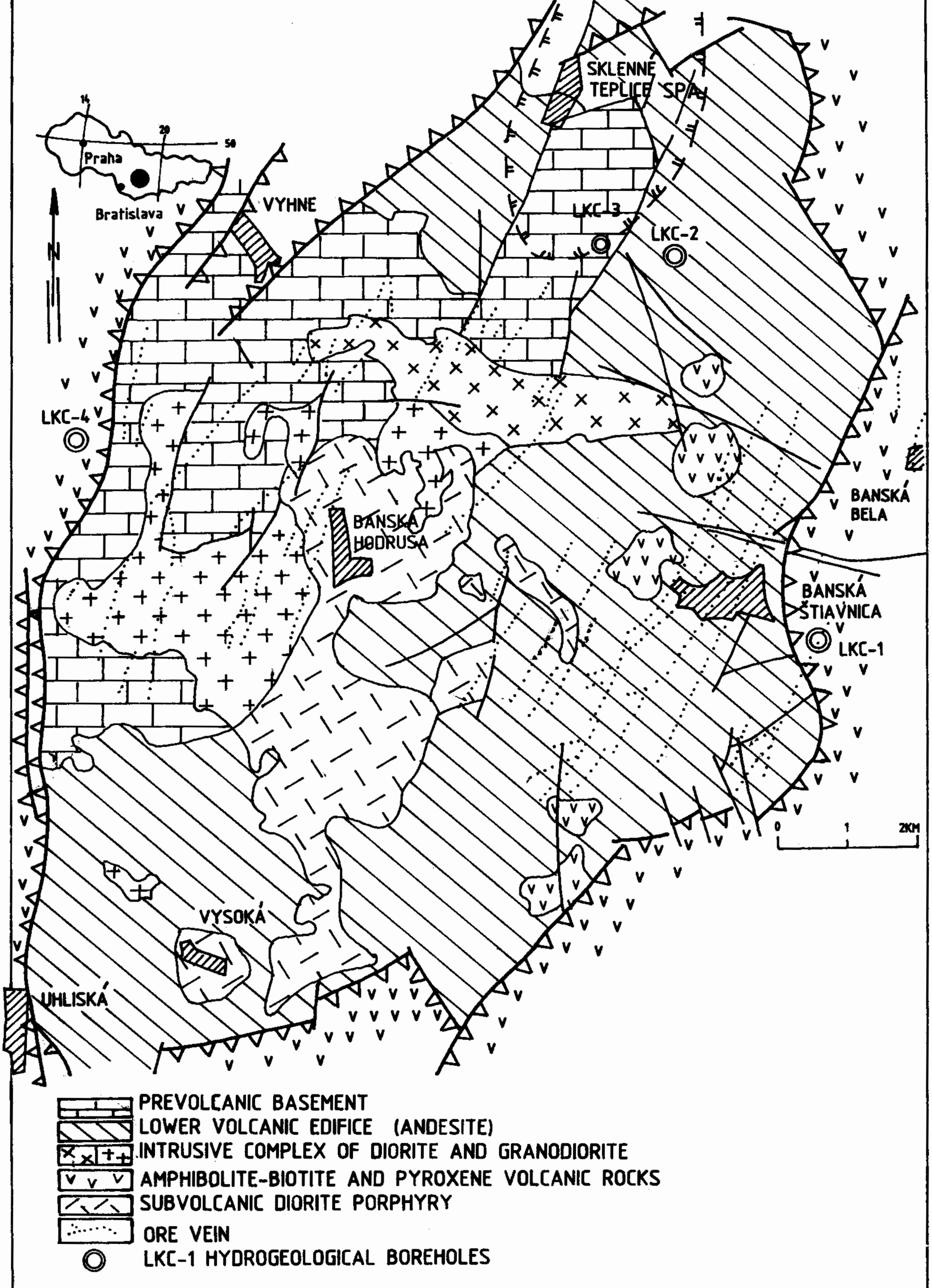
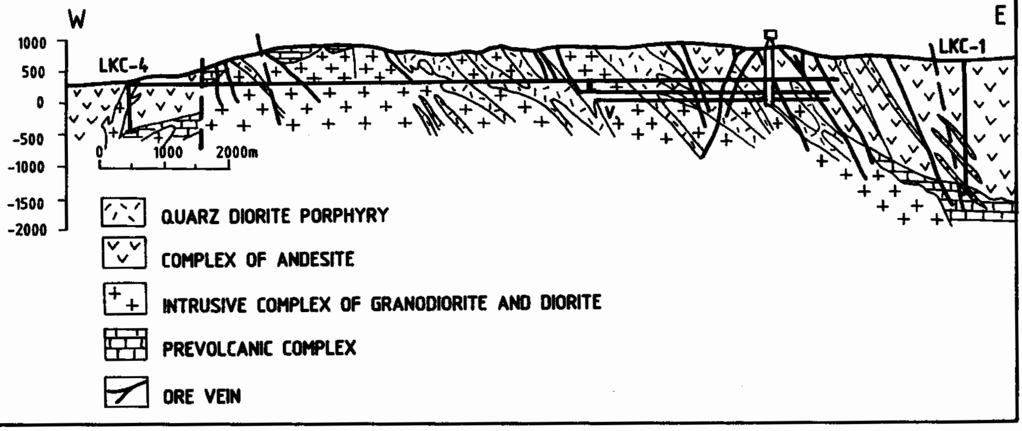


FIG.2 SCHEMATIC GEOLOGICAL CROSS-SECTION



As to mining conditions, the predominant part of ore reserves is represented by steeply dipping veins characterized by low to medium thickness and irregular displacement of workable mining blocks. The workings are scattered throughout the whole mining district and in case of slightly high exploitation they represent a serious problem of economic operation. The optimum development of mining had to be in accordance with geological survey works performed so that they would have been max. used from exploitation point of view. For establishing the available stage of face mechanization, economically recommendable width of workings with respect to the position of veins and reasonable gangue contamination had to be examined.

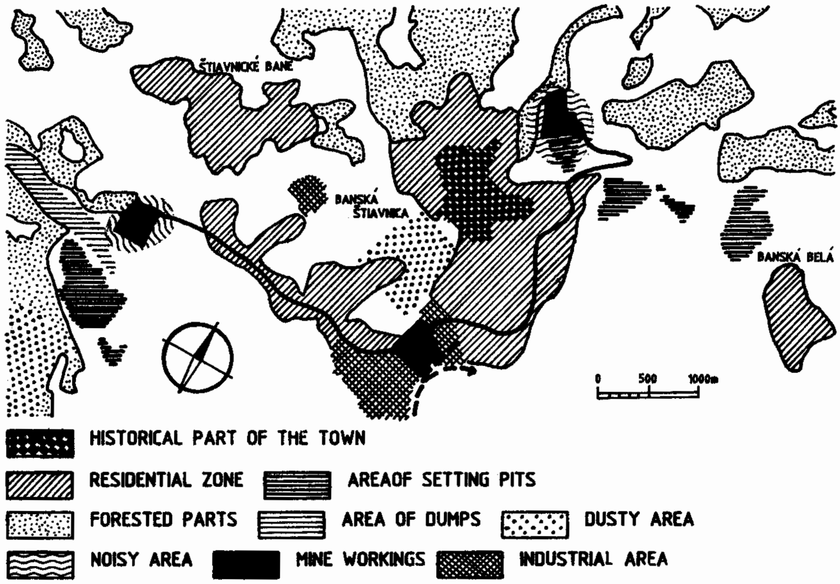
Because of great depths, shaft handling of ore and tailings of an output capacity of 1000 kt ore/year proved to be the most favourable one. The question concerning mining environment had to be solved with special respect to high temperatures and air humidity taking into consideration the presence of radon, too.

From ore processing point of view it is necessary to point out that mineralization is there represented by various types but on the basis of the present knowledge as to the spatial distribution of those, selective mining does not seem as favourable method. That is why a joint dressing of the individual ore type mixture is there considered with predominating polymetallic type. The ore dressing will consist in a three-step crushing, milling, flotation, condensation and filtration resulting in obtaining selective Pb,Cu,Zn, FeS_2 or Pb-Cu, Zn-FeS_2 concentrates as final products.

In case of selective flotation, increased attention has been paid to keeping to purity of waste waters by introducing non-toxic flotation, experiments concerning an increased utilization of recirculating water, etc.

A further serious problem lies in urbanistic requirements and regional correlations. Banská Štiavnica city is e.g. situated in the area of vein mineralization crossing. Though the position and emplacement of the subject veins does not seem to be a limiting factor from building foundation point of view, ore mining development has no doubt high impact on environment. When solving the tasks leading to economic exploitation, considerable attention is first of all to be paid to environmental assessement consisting mainly in preventing air pollution, water contamination and excess noise, respecting nature reserves and natural conditions necessary for leisure purposes, historical monument conservation and land protection, and at last good traffic facility and favourable dwelling condition formation. In addition to the overproduction of tailings, flotation sludge and presumably boiler house ash being the main sources of negative impact on environment it is first of all waste liquidation, which may be considered as the chief factor closely connected with the question of ore mining and dressing to be solved. Attention must be therefore paid to the correlations existing between the increasing amount of workers (and population) and increasing traffic and transport needs resulting in increased regional requirements. Mud setting and tailings dumping had to be made with respect to the landscape and strong relief characterizing the subject area. For regional correlations demonstrating Banská Štiavnica city development see Fig. 3.

FIG.3 TERRITORIAL RELATIONS OF BANSKÁ ŠTIAVNICA TOWN DEVELOPMENT AND MINING INDUSTRY



In addition to the questions mentioned the problem of dewatering was gradually emerging and in a certain stage of development it became the dominant one.

HYDROGEOLOGICAL CONDITIONS

With respect to further exploitation forecasting, a complex solution of the hydrogeological conditions applying to the whole region was necessary. It consisted mainly in the specification of the amount of groundwater inflows from

the whole ore district, determination of the relationship existing between the amount of inflows and time necessary for static groundwater resource dewatering as well as of the possibilities of encountering some deeper-seated thermal water sources and of possible impact by exploitation on such sources in the Sklené Teplice Spa. Considerable attention has been further paid to studying the individual aquifer qualities and to distinguishing of those in the wider vicinity of the ore district with special regard to geological-tectonic pattern between Banská Štiavnica and Sklené Teplice Spa. For successful solving these tasks mentioned, a whole complex of hydrogeological operations had to be carried out. From among them extensive regime observations of surface and groundwaters as well as deep hydrogeological borehole drilling necessary for finding out the geological-tectonic and hydrogeological conditions especially in the areas of unsufficiently known geological structure should be there first of all mentioned.
From hydrogeological point of view, the subject region is formed prevailingly by rocks characterized by fissure permeability. In less amount some smaller karst formations are to be found chiefly in Mesozoic limestones and dolomites.

Tertiary volcanic rocks constituting the predominant part of the ore district are represented by andesites, rhyolites, dacites and pyroclastics being there present in form of lava flows, dikes, cumulo-domes, veins and some other bodies with an irregular network of fissures of different density and width. Depending on the intensity of fissuring and the nature of fissures as well, the subject rocks are varying between permeable and water-bearing up to impermeable ones. Apparent fissuring may be observed in the vicinity of tectonic dislocations mainly and at the contact of rocks of different physical-mechanical properties. Inflows are usually unconcentrated and are related to strongly fissured complexes. The inflow amount is varying between 1 and 3 $l.s^{-1}$. Groundwater circulation is considerably influenced by driving,a great amount of workings having a long-lasting drainage effect.
Pyroclastic rocks (tuffs, agglomerates) are characterized by porous-fissured permeability greatly depending on tectonic deformations. The fissures (especially of near-surface weathering) are often filled with products of weathering. There are rocks of variable permeability and water-bearing capacity involved.
Sedimentary rocks of Tertiary and Mesozoic age reach the surface in the northern and northwestern part only but if not affected by denudation or tectonic reducing, they are underlying neovolcanites almost in the whole region. While in the northern part the carbonate rocks (blocks) are several hundred metres thick (near Vyhne), towards the south their thickness is decreasing to several tens of metres only.
From hydrogeological point of view, there are slightly water-bearing rocks referred to sandy-shaly facies on the one hand and carbonate rocks represented by limestones and dolomites typical of well fissured and fissured-karst perme-

ability on the other. Permeability has been proved by hydrogeological boreholes. The greatest amount of groundwater inflows into the workings (by direct encountering or after encountering tectonic lines and ore veins communicating with them) may be expected from Mesozoic rocks. In the Bieber Vein for example, 80 $l.s^{-1}$ of groundwater have been encountered in these rocks.
Granodiorites and Paleozoic schists are cropping out from beneath the surface near Banská Hodruša where is the top of a batholithe-type body covering an area more than 100 km^2. These rocks are slightly permeable.
The whole area is affected by germanotype tectonics characterized by lot of tectonic lines and associated ore veins.

In the course of geological history, repeating tectonic movements along the old fault systems took place there having been resulted in an intricate tectonic pattern origination. Numerous tectonic lines of considerable reach in depth and strike are there considered as the most important aquifer with the carbonate rocks together. Due to tectonic movement repeating, favourable conditions have been in the tectonic lines formed from accumulation and permeability points of view. The occurence of cavities being several dm wide is not rare there. The subject tectonic lines are draining the surrounding rock mass over a large area enabling in such a way groundwater communication over large distances. There are inflows concentrated nature and after encountering them, in-inrushes (several ten $l.s^{-1}$) may originate. The deeper seated parts of ore veins are thermal water aquifers (42-53°C). If these are encountered, apparent changes of climatic conditions take place in the underground workings.

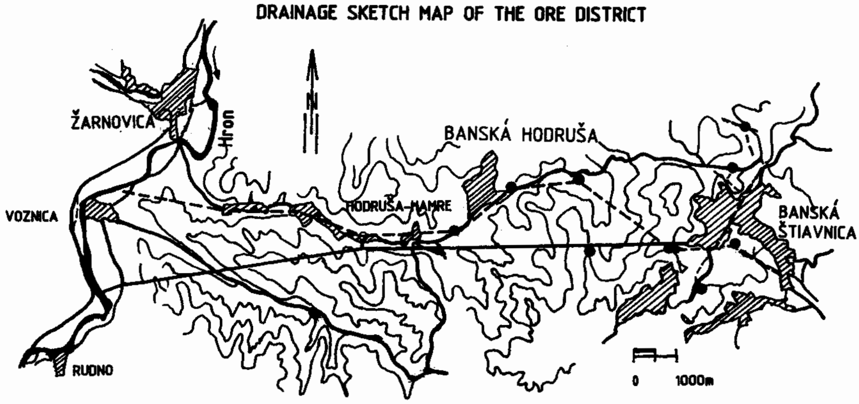
In the ore district an average amount 290 $l.s^{-1}$ of mine waters is outflowing through numerous drainage tunnels at the present time. Inflows are varying depending on the amount and intensity of inflows into new underground workings as well as on the precipitation intensity in the subject time. The influence of precipitation is apparent in the Banská Hodruša area chiefly where underground workings are relatively close to the surface. The predominant part of mine water inflows is referred to the Banská Štiavnica area. Those are prevailingly drained by the Voznica Drainage Tunnel driven in depth of 210-235 m a.s.l.(se Fig. 4). Future geological survey and exploitation operations will be realized on the Drainage Level only and deeper, i.e. on the IInd and Vth deep levels +94 and -110 m a.s.l.
The present situation of measurable groundwater inflows in the ore district is, as follows:

		Inflows $l.s^{-1}$		
Deposit	Level	min.	max.	average
Banská Štiavnica	Drainage Level	115,0	193,6	152,0
Banská Štiavnica	IIth Deep Level	14,0	19,0	16,8
Banská Hodruša	Drainage Level	6,5	8,5	7,5

These amounts, waters infiltrated from surface streams and some other unfixed ones should be added to.
In the course of geological survey works more than 150 km of galleries and several shafts are considered to be driven

FIG.4

DRAINAGE SKETCH MAP OF THE ORE DISTRICT



or sunk respectively. These operations will greatly influence not only the groundwater regime and the whole groundwater balance but there will be a high risk to be expected in connection with the technical performance of drainage because of considerable increase in groundwater inflows. When prognosing groundwater inflows, geological structure and lithological nature of the rocks as well as hydrogeological properties in tectonic lines and ore veins to be encountered by these workings had to be taken into account. In addition to the factors mentioned, time schedule of geological survey works and final drainage state of some part of the ore district by older underground workings should be considered, too. For expected amounts of static groundwater resources and inflows below the Drainage Level see the table:

Deposit	Stat.Resources (km^3) to IInd lev.	II-V.lev.	Drainage Inflows to 10 years($l.s^{-1}$)	
Banská Štiavnica	0,01632	0,01736	517,5	550,5
Banská Hodruša	0,00235	0,00319	74,5	101,1

After the static resources have been drained, perennial groundwater inflows from dynamic resources must be considered, as follows: Banská Štiavnica Deposit 110 $l.s^{-1}$ (up to the Drainage Level), 117 $l.s.^{-1}$ (IInd Deep Level) and 127 $l.s^{-1}$ (Vth Deep Level); Banská Hodruša Deposit 23 $l.s^{-1}$ (up to the Drainage Level), 28 $l.s^{-1}$ (IInd Deep Level) and 38 $l.s^{-1}$ (Vth Deep Level). When developing some deeper-seated levels, especially in case of the Grüner and Špitaler Veins, thermal water (35-50°C) inflows (25-40 $l.s^{-1}$) may be expected.

After re-evaluating all the possible proposals for successful elimination of the risk of enormous amounts of water inflows into the underground workings (increasing the Voznica Drainage Tunnel capacity, mine water pumping to the surface, etc.), construction of a quite new 13,8 km long drainage tunnel of straight direction and of uniform slope has been decided to be driven from the Drainage Level taking into account all the activities performed in individual parts of the mining district (geological survey works, increased exploitation, mine field drainage, etc.). The New Drainage Tunnel of a discharge profile of 1800 $l.s^{-1}$ is almost ready this time and has been made by combined way(classical driving and tunelling - see Fig. 4).

A long-lasting and trouble-free operation of drainage tunnel results from good-quality construction works and depends on the qualities of mine waters as well. Groundwaters are of vadose origin and are characterized by deeper circulation. From chemical composition point of view, there are typical remarkably calcium sulphate waters of a mineralization of about 1 $g.l^{-1}$. Mine waters have deterious effects on concrete and metal constructions because of high sulphate content mainly. High iron content (17 $mg.l^{-1}$) and mineral dispersion in groundwaters give rise to incrustation and sediments in the tunnel discharge profile. That is why not using metallic material in mine development has been there suggested. At the same time, proposals have been made for cleaning the drainage tunnel. Unfavourable consequences may be expected there after starting with operation and draining off mine waters into the Hron River. In mine waters there is a considerably high concentration of contamination elements. After mixing mine waters with surface stream ones, an increasing concentration of these compounds and impact on the recipient will there take place. From the recipient quality impact point of view, Zn/5,22 $mg.l^{-1}$ and Mn/4,7 $mg.l^{-1}$ are considered as unfavourable amounts. In cooperation with Water Economics Authorities it will be necessary to audit possible impact on the recipient and decide on eventual treatment of mine waters before draining off into the river.

References

1. Lukaj,M. Groundwater inflows to the Banská Štiavnica Deposit and the possibilities of their drainage on the rate of investigation works realization. Mineralia Slovaca, Vol. 9, pp 327-332 (1977).
2. Madera,O. and Podskalský,Z. The district of Banská Štiavnica from the point of view of further development of nonferrous metals ore mining. Rudy, Vol. 26, pp 184-193. (1978)
3. Skaviniak,M. and Gazdík, R. Základný výpočet zásob ložiska Banská Štiavnica-východ, Pb,Zn,Cu,Ag,Au. Manuscript (1986).
4. Burian,J., Slavkay,M., Štohl,J. and Tözsér J. Metallogenesis of neovolcanites in Slovakia. Mineralia Slovaca - Monografia, pp 1-269 (1985).