СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО, год. 80, кн. 3, 2019, с. 80–82
REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY, vol. 80, part 3, 2019, p. 80–82

Национална конференция с международно участие „ГЕОНАУКИ 2019"
National Conference with international participation "GEOSCIENCES 2019"

Geology, hydrothermal alteration, and ore mineralogy of the Zlatousha ore occurrence, Western Srednogorie, Bulgaria

Геология, хидротермално променени скали и рудна минералогия на рудопроявление Златуша, Западно Средногорие, България

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Keywords: Zlatousha, Western Srednogorie, geology, hydrothermal alteration, ore mineralogy.

Introduction

Zlatousha ore occurence is situated in the Western Srednogorie zone in Bulgaria which in regional aspect belongs to the Late Cretaceous Apuseni-Banat-Timok-Srednogorie magmatic and metallogenic belt (Popov et al., 2002) which hosts Cu- and Au-rich porphyry and epithermal deposits. The occurrence is northeast from Zlatousha village which is located 30 km west of Sofia.

Previous work conserning the Zlatousha ore occurrence presents data of the host rocks, hydrothermal alteration and some genetic aspects (Ferdov, Kunov, 2002). The aim of this study is to add new data of the geological settings, styles of alteration, and mainly to document the ore minerals and their chemistry with an attempt to constrain the genesis of the prospect.

Sampling and analytical techniques

The samples from hydrothermal altered rocks and ore mineralization are collected from the mineralized zones. Polished sections and polished thin sections were prepared to determine the paragenetic relationships of the ore minerals and to characterize the hydrothermal alteration assemblages.

X-ray powder diffraction (XRD) analyses were performed on a TUR M62 diffractometer using filtered Co-Kα radiation in the 2θ range 4–80°, step size 1.5° at Sofia University "St. Kliment Ohridski", Sofia, Bulgaria. Scanning Electron Microscopy and Energy Dispersive Spectroscopy (SEM-EDS) were done on carbon-coated polished sections with a SEM JEOL JSM 6610LV equipped with an EDS detector at the University of Belgrade, Serbia. Standards used were $CuFeS_2$ (Cu, Fe, S), metallic Mn (Mn), ZnS (Zn), InAs (As), metallic Se (Se), CdS (Cd), metallic Ag (Ag), Ag_2Te (Ag, Te), InSb (Sb), metallic Co (Co), metallic Ni (Ni), metallic Bi (Bi), PbS (Pb), metallic Au (Au).

Geology

Zlatousha ore occurrence is genetically and spatially related to Zlatousha paleovolcano (Bairaktorov, 1989; Velev, Nedialkov, 2010). The volcanic structure is located 1.5 km SW from Zlatousha village and 2 km SW from the ore occurrence. The paleovolcano center is not well preserved. The volcanic edifice is composed mainly of volcaniclastic (epiclastic and pyroclastic) rocks and less lava flows and volcanic plugs (necks). In most of the cases a sequence of epiclastic rocks overlain by pyroclastic agglomerate (bomb tuffs), covered by lava flows is distinguished. The layers of pyroclastic and effusive rocks are subhorizontal, with thickness between 2 and 6 m. Several dykes are also established. The two biggest dykes are 4–5 m thick and about 120 m long and oriented as the predominant part of the dykes in NW-SE direction. At the north and NW of the village isometric subvolcanic bodies intruded in volcaniclastic rocks and intensive hydrothermal alteration areas are established.

During the field work two extensive and homogeneous ore zones were mapped. The southern zone is about 7–8 m thick and it has northwest-southeast strike direction. The direction of the northern one is equal, but the thickness is more – 25–30 m. There is another fault system with north-east-southwest strike direction, which also hosts hydrothermal products.

The field results show typical structural control of the mineralization, which is hosted mainly by vertical strike-slip faults in two directions – NW-SE and NE-SW. The first group is represented by major strike-slip faults, and the second – by secondary faults.

Hydrothermal alteration

Hydrothermal alteration occurs northeast from the Zlatousha village and is hosted predominantly by volcaniclastic rocks. The styles of alteration are sericitic, argillic and propylitic. Alteration mineralogy is based on investigations using optical microscopy and XRD analyses.

Propylitic alteration is extensive and it surrounds sericitic alteration. The mineral alteration assemblage is carbonate-chlorite. Relict porphyry texture represented by primary pyroxene and plagioclase phenocrysts can be observed. Carbonates are the most common and they occur in the groundmass and in amygdales (vesicles) together with chlorite and zeolites which according to XRD are determined as lomontite and stilbite.

Sericitic or quartz-sericite-pyrite (QSP) alteration is the most common type in the occurrence. It occurs in two zones which are structure-controlled by strike-slip faults. The alteration consists of fine-grained quartz and sericite, ore minerals (mainly euhedral to subhedral pyrite), and clay minerals (illite, proven by XRD). The original rock texture is preserved and represented by plagioclase altered to sericite and amphibole phenocrysts partly or completely altered to sericite, illite and later zeolites. Rare amygdales, filled with sericite, quartz, and zeolites also can be observed.

Argillic alteration is rare, it occurs in the outer parts of the two hydrothermal zones and consists of quartz, plagioclase, kaolinite, montmorillonite, chlorite, illite, whose presence is indicated by XRD analyses.

Ore mineralogy and mineral chemistry

Ore mineralization is hosted by the sericitic alteration zones where the pyrite is the main ore mineral. The most common textures of ores are disseminated and nest-like, formed dominantly from pyrite. On the basis of mineral assemblages and depositional sequence, the mineralization can be referred to one ore stage – quartz-polymetallic, which is represented by pyrite, sphalerite, and minor galena and chalcopyrite. The main gangue mineral is quartz.

Pyrite is the most common ore mineral and it occurs as disseminated single crystals and as aggregates in nests with size from <10 μm up to 500–1000 μm. Usually it is subhedral to anhedral, rarely euhedral with predominant size of the crystals in the range 10–50 μm. Numerous inclusions of galena, chalcopyrite and gangue minerals can be observed in pyrite.

The LA-ICP-MS dataset in the pyrite of Zlatousha shows variable concentrations of trace elements. High concentration of As (from 25.44 to 7000.35 ppm, average 1955.27 ppm), Pb (from 41.67 to 8744.44 ppm, average 661.79 ppm), Mn (from 47.77 to 1638.87 ppm, average 308.59 ppm) were detected. Cu and Zn are respectively up to 476.41 and 650.22 ppm. Sb, Ni, Co, Ag are with lower contents. Au reaches 1.34 ppm and average 0.73 ppm. In most cases, these elements display irregular profiles which are illustrated on the depth spectra as spikes. These spikes show lack of homogeneity in the ablation spot suggesting the presence of micro-inclusions of minerals adsorbed in pores and microfractures (Sabeva, Georgieva, 2019).

Sphalerite occurs as anhedral grains up to 70 μm (rarely up to 200 μm) among the pyrite aggregates. Irregularly distributed small chalcopyrite inclusions, known as "chalcopyrite disease" are observed in sphalerite. Some of sphalerite crystals have rims or net-mesh-like microtextures of blue mineral which according to SEM-EDS analyses is covellite(?) with 65.32 and 65.57 wt% Cu.

SEM-EDS analyses show trace elements which are typical for sphalerite as Fe, Cu, Mn, and Cd. Iron concentrations range from 0.56 up to 2.72 wt%, only one analysis shows 6.02 wt%, which define the sphalerite as Fe-poor. Therefore, iron contents are not determinant for the formation of chalcopyrite disease (Bortnikov et al., 1991). Copper contents vary from 0.53 to 3.86 wt% and probably are due to chalcopyrite inclusions. Manganese concentrations are common in sphalerite and range from 0.26 to 2.71 wt%. Sphalerite is the main ore of Cd but at the Zlatousha Cd is established only in one analysis with trace contents of 0.12 wt%.

Galena is rarer than sphalerite. Under microscope it is hard to be distinguished but SEM analyses affirm its presence. It occurs as anhedral inclusions in pyrite and sphalerite with size around 5 μm. Rare disseminated single crystals also can be observed among the quartz-sericite groundmass. SEM results indicate a deviation from the stoichiometry because of the very small grain size of galena, but they reveal the presence of Fe, Zn, and Bi as minor elements.

Chalcopyrite occurs mainly as inclusions in sphalerite as "chalcopyrite disease" and rare as inclusions up to 40 µm in pyrite.

Discussion and conclusions

The Zlatousha ore occurrence is presented mainly within altered volcaniclastic rocks and rare within subvolcanic bodies of Late Cretaceous age, products of the Zlatousha paleovolcano. The two main ore zones are structure- controlled and hosted by NW-SE-striking faults, which belong to regional strike-slip fault system.

The ore mineralization associates with sericitic alteration with illite. The occurrence is sulfide-poor, dominated by pyrite with up to 1.34 ppm Au, Fe-poor sphalerite and minor galena and chalcopyrite.

These features of the Zlatousha ore occurrence correspond with low sulfidation state of fluids (Einaudi et al., 2003; Sillitoe, Hedenquist, 2003). Ferdov and Kunov (2002) also define the occurrence as adularia-sericite epithermal type, i.e. low sulfidation type.

The present investigation and the new data of the geological settings, alteration style, ore mineralogy and composition of some minerals confirm the low sulfidation type epithermal genesis of the Zlatousha ore occurrence.

Acknowledgments: This work was financially supported by the DM 04/2 grant from 13.12.2016 of the National Science Fund Bulgaria.

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