Trace elements in pyrite from the Milin Kamak epithermal gold deposit, Western Srednogorie: A LA-ICP-MS study

Елементи-следи в пирита от епитермално златно находище Милин Камък, Западно Средногорие: LA-ICP-MS изследване

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Introduction

The Milin Kamak epithermal gold deposit is located 2 km southern from town of Breznik and covers a 3500 m by 1500 m area. Euromax Resources Ltd. explored the deposit between 2004 and 2010 by 100 tranches and 121 drill holes. The probable reserves and resources at a cutoff grade of 2 g/t are 4 088 267 tons with an average content of 5.04 g/t gold and 13.01 g/t silver.

Materials and methods

Representative samples were collected from drill cores intersecting 5 mineralized zones of the deposit. Trace element concentrations in pyrite were measured by LA-ICP-MS on polished sections at the Geological Institute (Bulgarian Academy of Sciences). The analyses were made using the PerkinElmer ELAN DRC-e ICP-MS equipped with a New Wave UP193-FX excimer laser ablation system. NIST SRM 610 glass was used as external standard. The laser system was operated at constant 10 Hz pulse rate; laser energy was 10.10 J/cm^2 on SRM 610 glass and 1.90–3.06 J/cm^2 on sample. Spot size was 50 μm in diameter. A total of 92 analyses were made and 48 isotopes were monitored. Acquisition dwell time for all masses was set to 0.01 s. Data reduction was undertaken using SILLS ver. 1.1.0 software (Guillong et al., 2008) and Fe as internal standard. Iron contents in pyrite were measured by electron microprobe at the Institute of Earth Sciences, University of Graz, Austria.

Geological settings and mineralization

Milin Kamak gold deposit is hosted in Upper Cretaceous trachybasalt and basaltic trachyandesite (Western Srednogorie zone). Subsequent Palaeogene and Neogene sediments are superimposed on the volcanic rocks. Eight parallel mineralized zones, which correspond with E–NE fault zone, were outlined. Argillic, quartz-sericitic and sericitic alterations are typically associated with the ore. The outermost alteration zone is propylitic. The ore minerals occur mainly as stockworks and disseminations in quartz, carbonate and sericitic matrix. A three-stage mineralization parageneses were distinguished: Quartz-pyrite (Stage I), Quartz-polymetallic sulfide (Stage II) and Carbonate-gold (Stage III). The most abundant ore mineral is pyrite.

Results of LA-ICP-MS analysis and conclusions

Different morphological types of pyrite were observed by reflected-light microscopy, but LA-ICP-MS data give clear differences in minor and trace elements contents. Three different chemical types of pyrites can be distinguished.

Type I – “Pure” pyrite is semihedral to euhedral, also characterized by lack of inclusions and no cracks. Data from analyses show no gold content and very low concentrations of other trace elements.

Type II – Pyrite with high concentrations of trace elements is porous and fractured. Probably, these microfractures and multiplicity of cracks and pores favor the mechanism of adsorption of the elements and incorporates a variety of inclusions (including gold).

Type III – Copper-containing pyrite is also rich of gold and is in assemblage with several copper minerals.

The LA-ICP-MS dataset shows variable concentrations of trace elements in type II pyrite. High levels of Mn (from 4.82 to 9898.14 ppm, average 286.68 ppm), Co (from 0.27 to 3568.52 ppm, average 204.47 ppm), As (from not detectable to

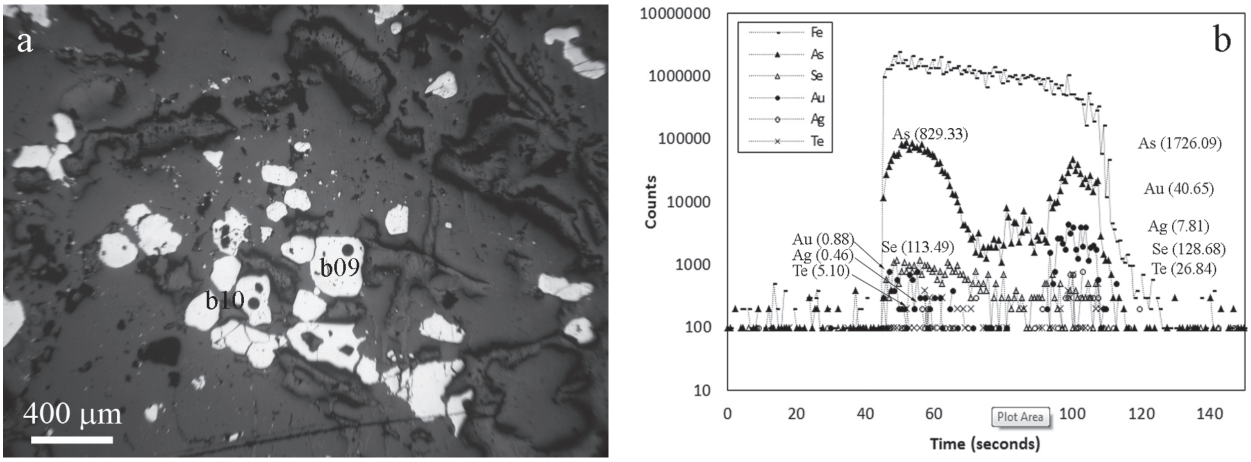

Fig. 1. Depth spectra of pyrite: *a,* pyrite grain from drill hole 10109, depth 155.8 m, analyzed spots b09 and b10 are shown; *b,* representative LA-ICP-MS spectra for selected elements in spot b10. Numbers in brackets are concentrations (in ppm).

14454.76 ppm, average 1706.99 ppm), Pb (from not detectable to 5835.26 ppm, average 170.39 ppm) and Bi (from not detectable to 92.40 ppm, average 16.14 ppm) were established. The elements with low concentrations or below detection limits are Ga, Ge, Mo, Sn, Tl, Cd, In.

Type II and type III pyrite contain Au from not detectable to 40.65 ppm (average 4.07 ppm) and Ag from not detectable to 20.58 ppm (average 1.91 ppm). In most cases, these elements display irregular profiles (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 containing those elements (adsorbed in microfractures). A typical example of this is the depth spectra of gold and silver in sample 10109/12 (especially in spot b10, Fig. 1).

Generally, the dataset shows positive correlation of Au with Ag, Mn, Sb and no correlation of Au with Co, Ni, also with Cu, Te, Pb. Values of As, which is considered as essential for incorporation of invisible gold in pyrite, are variable (from not detectable to 14454.76 ppm) and generally there is no correlation with Au. However, in several single samples (1097, 10109/7, 10109/15 and 10114/3) it is established positive correlation between Au and As. Thus, As is important for gold entrance in lattice in some of pyrite grains.

The LA-ICP-MS analysis is powerful method to study the different types and generations of pyrites, to give hopeful data about microcomposition. It is an indirect way to decipher the genetic code of the mineral.

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