

Trace elements vectors in minerals from Elatsite PCD, Bulgaria

Елементи-следи вектори в минерали от медно-порфирно находище Елаците, България

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Introduction. Trace elements pathfinders in magnetite, chalcopyrite, molybdenite and late D-type pyrite toward porphyry systems have been tested on the example of Elatsite porphyry-copper deposit, Bulgaria. Similar studies providing new data and assessment of the possibility to use the trace elements in the most common ore minerals in different types of deposits are presented by Dare et al. (2014), Cook et al. (2014, 2016), Bogdanov and Krumov (2016), etc. Following the distribution and the change of concentration of trace elements in pyrite, chalcopyrite, magnetite and molybdenite along an entire metallogenic province or even in a single deposit can be used as an exploration tool for targeting porphyry and epithermal systems. Furthermore, depending on comparison of the mean and the grade of specific trace elements in magnetite and pyrite can be suitable geochemical criteria for classifying the source of studied mineral grains – hydrothermal, magmatic or sedimentary (Bralia et al., 1979; Dare et al., 2014).

Methods. This study is based on 175 LA-ICP-MS analyses (Perkin-Elmer ELAN DRC spectrometer with New Wave UP193FX LA device, property of Geological Institute-BAS) from secondary magnetite and M-type (early magnetite ± actinolite, biotite, ± quartz), A-type (quartz-pyrite-chalcopyrite), B-type (quartz-molybdenite ± chalcopyrite) and late pyrite D-veins (Fig. 1). Samples were selected from 13 drill holes, covering a depth of 500 m and lateral N-S extent of 1.4 km. Most of the samples were collected from the Paleozoic Vezhen pluton while fewer are taken from the contact metamorphosed greenschists (Diabase Phyllitoid Complex) and Upper Cretaceous quartz-monzodiorite porphyries.

Results and discussion. Titanium, Mg, V, Cr, and Mn are the most common trace elements in the secondary magnetite that has been developed by replacing mafic minerals in addition to early magnetite veins. The Ti content varies from 90.56 ppm to 8.61 wt%, Mg from 53.78 ppm to 2.14 wt%, V from 35.91 ppm to 1.95 wt%, Cr from 67.28 to 1392.90 ppm, and Mn from 199.29 to 2142.47 ppm. High Ti (8.61 wt%), and

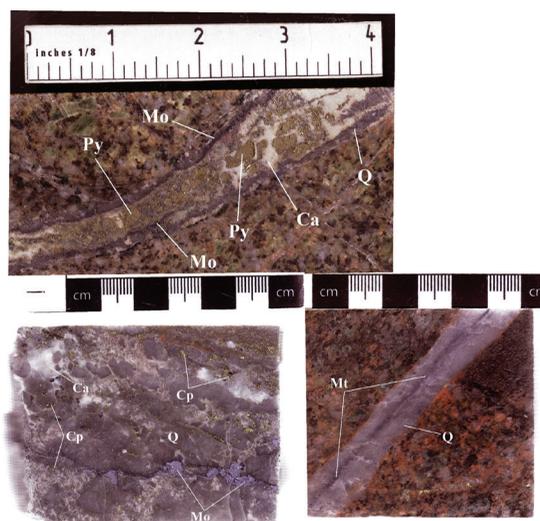


Fig. 1. Drill-core samples from Elatsite showing the studied minerals. Abbreviations: *Ca*, carbonate; *Cp*, chalcopyrite; *Mo*, molybdenite; *Mt*, magnetite; *Py*, pyrite; *Q*, quartz.

Mg (2.14 wt%) grades are probably due to mineral inclusions of rutile/titanite and carbonate minerals. Cobalt, Ni, Zn, Ga, Sr, and U are with constant quantity but rarely more than 100 ppm. Taking into account the concentration of Ni, Cr, Ti, V, and Mg (Canil et al., 2015), the magnetite from Elatsite is formed in a porphyry system but more than a half of the analyzed grains are with magmatic origin, which are mainly situated in the deeper SW parts of the deposit (Fig. 2).

Abundant trace elements in chalcopyrite are Ni (from 140.99 to 230.69 ppm), Mn (26.66–44.36) and Ag (0.50–60.74 ppm). In smaller quantities there is also Se, Zn, Ti, Cr, Mg, Zn, As, Cd, In, Sn, Sb, and Pb. The concentration of Ni, Pd, Ti, Cr, Sb, In, and As is a result of substitution of Fe while Ag, Zn and Cd more likely substitute Cu into the lattice of chalcopyrite. Also, direct ion exchange is favorable for the sulfur and selenium. It can be assumed that the high levels of Pb, Bi, Mn, and Mg are result of galena or Pb-Bi sulfosalt and Mn-calcite micro-inclusions.

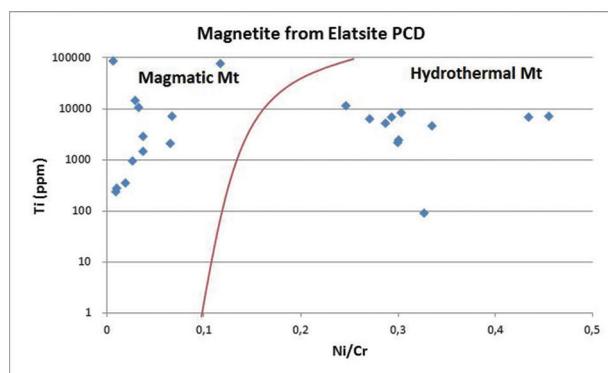


Fig. 2. Plot of Ti (ppm) vs Ni/Cr ratio (un-normalized) in magnetite (Mt) showing that more than a half of analyzed mineral grains are with magmatic origin (based on Dare et al., 2014)

The molybdenite samples were collected from the Vezhen granodiorites (NE and NW sectors) and also from the quartz-monzodiorite porphyries in the southern deposit part. Rhenium, Cd, Ag, Te, Ba, Co, Se, V, Pb, and Bi are the most abundant trace elements in molybdenite. Re concentration varies from 650 to 5707 ppm and increases towards the deeper parts of the deposit (Fig. 3). Average Re content is more than three times higher in the porphyries (3743 ppm) as compared to the granodiorites (1174 ppm).

Magnesium, Ti, Cr, Mn, Co, Ni, Cu, Ge, As, Se, Sr, Te, Pb, and Bi are the most common trace elements in the late pyrite-rich D-veins hosted in the Vezhen granodiorites. Cobalt content varies from 0.79 to 3025 ppm, Ni from 1.87 to 947 ppm, As from 0.52 to 1023 ppm, Se from 41 to 1487 ppm, Te from 0.60 to 60 ppm, Ge from 0.22 to 25 ppm, and Bi from 0.04 to 6.99 ppm. Germanium, As, Se, Ni, Bi, and Te contents are higher in the deeper southern parts of the deposit (~785 m), while Cr and Co stay relatively constant. The average Co/Ni ratio (~88) in pyrite from the late D-veins in Elatsite proves its hydrothermal genesis (Bralia et al., 1979).

Conclusions. Taking into account that the Cu and Mo grades increase towards the center of the Elatsite PCD system, located in the granodiorites and the monzodiorite porphyries in the deep southern and SW parts of the deposit, the recent study provides a preliminary basis to be determined that:

- Ti, V, Cr, Mn, Sr, and U in magnetite increase in order of magnitude from 1 to 10 times from the marginal to the central parts of the porphyry system while Mg, Co, and Ni levels are 3 times lower. Based on the concentration of Ni, Cr, Ti, V, and Mg, the magnetite from Elatsite is formed in a porphyry system but more than a half of the grains are with magmatic origin.

- Zn, Se, In, Sn, and Bi in B-type chalcopyrite increase in order of magnitude from 1 to 2 times towards the center of the system while the levels of Mg, As, Ag, Sb, Ti, and Cr are from 1 to 5 times lower. The decrease in Mg, As, Ag, and Sb may be due to their

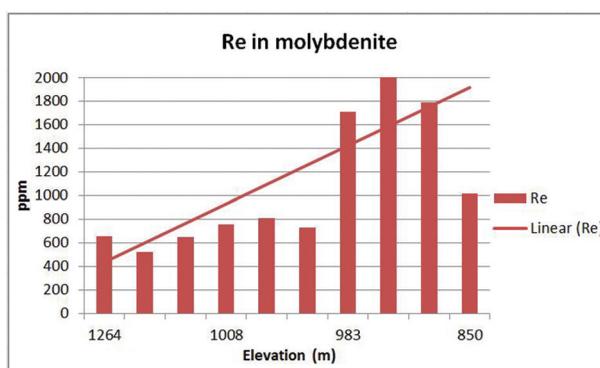


Fig. 3. Binary plot showing the change of Re content (ppm) in molybdenite and its linear trend of increasing to the deeper parts of Elatsite deposit

link to late low-temperature mineralization (<250 °C), such as carbonates and As-Sb±Ag sulfosalts, which are typical for the upper and marginal parts of the Elatsite porphyry system.

- Re concentration in molybdenite increases, while the Co, Ag and Cd content decrease towards the central and deeper parts of the Cu-porphyry system. The average Re content is more than three times higher in the quartz-monzodiorite porphyries as compared to the Vezhen granodiorites.

- Ge, Se, Ni, and Te in the D-vein pyrite increase in order of magnitude from 2 to 100 times from the marginal to the central parts of the system while Bi, As, and Co are from 2 to 5 times lower. The high Co/Ni ratio is a sign that the late pyrite being with hydrothermal origin.

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