Crystal morphology and thermal EMF of pyrites in the western flank of Sukholozhsky gold ore field (Lenski ore area)

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Abstract. The investigated crystal morphology and thermal EMF of pyrites in the western flank of Sukholozsky ore field showed that the pyrite crystals have cubic habitus with a weakly-developed face {210}. The crystal faces {100} and {210} are covered with multiple irregular-oriented growth laminae. It has been determined that pyrites have such a property as p-type conduction and embrace insignificant thermal EMF variations. The results of the research indicated the fact of upper ore zone erosion in the western flank of Sukholozhsky ore field and its area potential at depth.

1. Introduction

Although gold mining in Lenski ore area has been conducted for more than two centuries, early geologic setting of this gold placer area and its developed socio-economic environment were described by V.A. Obruchev only at the beginning of the 20th century. Further geological prospecting involved a total gold placer exploration and increasing placer resources development. It was only during the latter half of the 20th century that the priority of geological prospecting embraced the exploration of gold orebodies. Regardless the prolonged exploration of gold orebodies [1, 2], their genesis and substance sources still remain the object in issue, as well as the factors and features of gold mineralization. The major task in geological exploration is to determine the upper ore zone erosion. The topomineralogical analysis effectively identifies the mineral formation and distribution in different geological systems, as well as the potential mineralization at depth [3]. The most widespread and extensively studied mineral in gold ore deposits is pyrite [4].

Based on the multi-year investigations of pyrite in gold ore deposits with composite genesis, a series of common factors was established [3, 5].

The crystal morphology of pyrite consistently changes within ore bodies and deposits. For example, pyrite in the top of ore bodies and deposits has predominantly cubic crystal habitus, where the face {210} is either absent or weakly and unevenly developed; while in the mid of ore bodies, especially in “ore chimneys” containing maximum gold grade, the face {210} is habitus in crystals and pyrite crystals are predominantly pyritohedron.

Pyrite is classified as a mineral with p-type impurities. Stoichiometrically-pure pyrite has such a property as p-type conduction. Monad and dyad elements (Ag, Sb, Hg, Pb, Zn, Cu), isomorphous constituent mineral, increase and / or decrease p-type constituent thermal EMF value, while triad and tetrad elements (Ni, Co, As, Ti, W), isomorphous substituent iron or sulphur, change pyrite p-type conduction to n-type conduction. It was also determined that [3] the following factors influence the value and sign of pyrite thermal EMF: temperature differential between cold and hot electrodes (the higher the temperature differential between the electrodes, the higher the p-type and n-type conduction), natural background and artificial radiation of the mineral, crystallographic line (embracing the measurement itself), deposit formation temperature and depth, and, respectively, the pyrite isomorphic volume of the crystal lattice.

The research showed that in the case of thermal EMF pyrites from ores and wallrock metasomatites of gold ore deposits with different genesis, the thermal EMF is responsive typomorphic attribute and consistently changes in time and space from pyrites with electron conduction within early high-temperature mineral associations and root section of orebodies to pyrites with mineral associations and mixed-type conduction from medium-temperature and mid-section of orebodies, as well as pyrites with p-type conduction during the final deposit formation stages and upper section of orebodies. According to the thermal EMF pyrites, it is possible to identify the deposit formation conditions, orebody zone erosion, and, consequently, their area potential at depth and on the flanks [3].

The following research is focused on the investigation of crystal morphology and thermal EMF of pyrites in the western flank of Sukholozsky ore field to determine the mineralization zone erosion.

2. Regional setting

The structure and composition of rocks and ores in Sukholozsky ore field have been described in details in many publications [1, 2, 6, 7]. A brief description of the western flank of Sukholozsky ore field is as follows (figure 1).

The ore field is within the Bodaibo syncline, Kropotkinore ore cluster, where its western flank is stripped by surface mining and core drilling. Sukholozsky anticline is the major structure controlling the ore localization. It is a linear, highly compressed asymmetric fold, elongated to the E-W and southward vergent. The northern and southern anticline flanks dip at the angles of 15…20° and 30…45°, respectively.

The orebodies in the western ore field flank is limited to the sediments of the upper Khomolkho suite subformation and the lower Imnyakh suite subformation, formed of sandstones, aleurolites and phyllites of different grain sizes. The rocks within these suites were exposed to regional metamorphism of chlorite-sericitic subfacies in greenschist facies.

Hydrothermal carbonization reveals carbonate, sulphide and quartz-veined mineralization. Ore mineralization is confined to disjunctive folded dislocation zones, embracing vein-disseminated quartz-sulphide and quartz-veined mineralization.

3. Research methods

The study of pyrite crystal morphology (figure 2) was based on the selected samples [3] from the western flank ore zones of Sukholozsky ore field.

Pyrite thermal EMF identification was conducted on an integrated double-microscope MBS-10, designed to measure the thermal EMF of small solid mineral fractions ranging from 0.2 to 1.0mm (in the Geology of Gold Lab, TPU). A cold solid 20×10×0.5cm plate brass electrode and a hot brass needle-shaped electrode are connected to the digital milliammeter M-800F, automatically measuring either electron (–*n*) or p-type (+*p*) conduction of a mineral.

The measurement was conducted under the conditions of the constant temperature difference of 150 ^{o}C between cold and hot electrodes. The calibration testing of the electrode- establishment of temperature difference between cold and hot electrodes and conduction type – was performed by the reference sample-galena, which has only n-type conduction. Check measurements of reference galena were performed at 10-15 sampling intervals. Thermal EMF measurement time of a mineral is

15…20 sec. Every sampling includes 30-50 thermal EMF measurements of grains and / or mineral crystals.

The crystal morphology and thermal EMF were studied in tens of pyrite crystal samples.

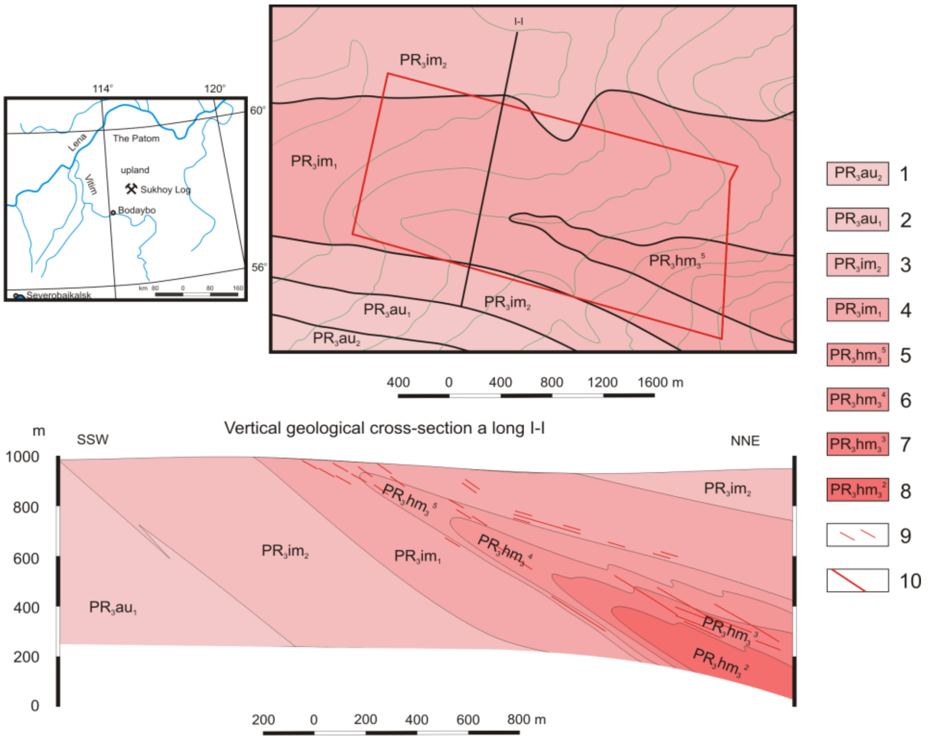

Figure 1. Sketch map of the geological structure of the western flank of Sukholozsky ore field according to [8] and commentaries of the authors.

Legend: *Aunakit suite* (1–2): 1 – middle subformation: quartzitic sandstone interlayers; 2 – lower subformation: alternating carboniferous shale, quartzite and limestone sandstone and limestone; *Imnyakh suite* (3–4): 3 – upper subformation: white and / or creamy, slightly greenish limestone, limestone sandstone layers; 4 –lower formation: rhythmical alternating shale, limestone sandstone and limestone layers; *Khomolkho suite* (5–8): 5 – 5th horizon: phyllitic shale, carbon interlayers of aleurolites and quartzite-mica sandstones; 6 – 4th horizon: quartzite-mica aleurolites; 7 – 3rd horizon: rhythmical alternating carbon shale, aleurolites and quartzite-mica sandstones; 8 – 2nd horizon: high-carbon shale; 9- small ore-hosting faults; 10 – licenced area contour.

Figure 2. Inclusions of pyrite crystal in phyllite.

4. Research results

Pyrites in the western flank of Sukholozsky ore field are cubic{100} or cubic with weakly-developed pyritohedron faces {100}+{210}, ranging from 1.o to 4.0cm. Random crystals have a regular shape, but more often, they are flattened or weakly pseudorhombohedral. The faces {100} are covered with intricated sheet growth laminae. Faces {210} are weakly developed and are also covered with growth laminae. The growth laminae on crystal faces are very thin and do not have regular outlines relative to crystal edges. Crystal faces often show irregular imprints of hosting rocks (argillites, phyllites) and quartz. Internal crystal structures are not always compact due to entrapping hosting rocks and weak conchoidal fracture.

The investigated thermal EMF showed that pyrites have only p-type conduction with thermal EMF value scatter from 27 to 83mV and near mean value ranging from 58.4…67.0 mV (table. 1). Thermal EMF value involves a regular distribution in every investigated crystal (V=12.2…17.3 %).

Table 1. Statistic parameters of pyrite thermal EMF distribution in the western flank of Sukholozsky ore field.

No.	Sample No.	Number of measurements	Thermal EMF, mV			Standard error (S)	Coefficient of variation (V), %
			min	*max*	$x_{cp.}$		
1	3-4	47	33	80	59.6	9.7	16.3
2	3-5	38	40	78	66.9	8.7	12.2
3	3-6	42	27	83	67.0	12.5	18.7
4	3-7	50	35	77	58.4	11.2	17.3
5	3-8	39	31	75	62.5	10.1	15.3

5. Conclusions

Investigated pyrite crystals have only cubic habitus which is characteristic of the pyrites located in the top of ore bodies. The p-type conduction of pyrites indicated the fact of upper ore zone in the western flank of Sukholozsky ore field [3]. The research results do not contradict the stated conclusions of previous investigated gold ore areas [9, 10].

Therefore, the analysis of the crystal morphology and thermal EMF of pyrites revealed insignificant (upper ore) gold mineralization zone erosion. Another important factor is the potential gold resources in the central and eastern areas of Sukholozsky ore field within Khomolkho suite horizons and stratigraphically located vertically below.

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References

[1] Sher S D 1966 Okolorudnye izmeneniya, soputstvuyushchie zolotokvartsevym zhilam v Lenskom zolotonosnom rayone. *Metasomaticheskie izmeneniya bokovykh porod i ikh rol v rudoobrazovanii*. Ed. N I Nakovnik (Moscow: Nedra) pp 282–291 (in Russian)

[2] Burjak V A and Hmelevskaja N M 1997 *Sukhoj Log – odno iz krupnejshikh zolotorudnykh mestorozhdenij mira (genezis, zakonomernosti razmeshchenija orudenenija, kriterii prognozirovanija) (*Vladivostok: Dalnauka) p 156 (in Russian)

[3] Korobejnikov A F, Narseev V A, Pshenichkin A Y and Revjakin P S 1993 *Pirity zolotorudnykh mestorozhdenij (svojstva, zonalnost, prakticheskoe znachenie) (*Moscow: CNIGRI) p 213 (in Russian)

[4] Koglin N, Frimmel H E, Minter W E L and Brätz H 2010 Trace-element characteristics of different pyrite types in Mesoarchaean to Palaeoproterozoic placer deposits *Mineralium Deposita* **45** 259–280
[5] Pshenichkin A Y, Oskina Y A, Savinova O V and Dolgaya T F 2014 Gold in Pyrite within Altai-Sayan Folded Belt Gold Deposits *IOP Conf. Ser.: Earth Environ. Sci.* **21** 1–4
[6] Large R R, Danyushevsky L V, Chang Z, Maslennikov V V and Robert F 2007 Multistage sedimentary and metamorphic origin of pyrite and gold in the Giant Sukhoi Log deposit, Lena Gold Province, Russia *Economic Geology* **102** 1233–67
[7] Gavrilov A M and Kryazhev S G 2008 Mineralogo-geokhimicheskie osobennosti rud mestorozhdeniya Sukhoy Log *Razvedka i okhrana nedr* **8** 3–16
[8] Gavrilov R Y 2014 Geohimicheskaja zonalnost rudovmeshchajushchego oreola mezotermalnogo zolotorudnogo mestorozhdenija Zapadnoe (Lenskij rudnyj rajon) *Geologija i mineralno-syrevye resursy Sibiri* **17** 59–67
[9] Timkin T, Lavrov D, Askanakova O and Korotchenko T 2014 *IOP Conf. Ser.: Earth Environ. Sci.* **21** 1–6
[10] Cherkasova T Y, Timkin T V and Savinova O V 2015 First native silica findings in bismuth from garnet skarns of Ribny Log-2 gold ore target in Topolninsk ore deposit (Gorny Altai) *IOP Conf .Ser.: Earth Environ. Sci.* **24** 1–5
[11] Voroshilov V G, Savinova O V, Ananjev Y S and Abramova R N 2014 Anomaly Geochemical Fields in Siberian Hydrothermal Gold Deposits *IOP Conf. Ser.: Earth Environ. Sci.* **21** 1–6