

# Peculiarities of pyrrhotite mineralization in the Chertovo Koryto deposit (Patom Uplands)

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**Abstract.** Pyrrhotite mineralization of black shale gold-ore deposit in the central part of Chertovo Koryto (Patom Uplands) was studied. It was found that pyrrhotite consists of three generations, containing hexagonal and monoclinic modifications in various proportions. The increase in the monoclinic modification from the earlier to later generation was observed.

## 1. Introduction

Pyrrhotite is widely distributed in the deposits of various genetic types, including hydrothermal gold deposits. It is usually associated with sulfides (pyrite, sphalerite, galena, chalcopyrite, and arsenopyrite), chlorites, carbonates (calcite, ankerite), and quartz and forms several generations. For example, in comparison with such deposits as Ta Nang (Central Vietnam), Kumtor (Kyrgyzstan), Sukhoy Log (Russia), where it forms 1-2 generations, pyrrhotite is represented by 3 generations in deposits Awanda (China), Blagodatnoe, Olimpiada (Russia), and its quantity allows relating it to the primary ore minerals [1, 2, 3, 4].

Geological interest to study pyrrhotite is connected with its variable chemical composition. The iron content varies from 46.5 to 50 at.%. The chemical composition of natural pyrrhotites is characterized by intermittent series: monoclinic – 46.45...46.9 at.%, hexagonal – 47.0...48.3 at.%, troilite – 49.8...50.2 at.% [5, 6]. All pyrrhotites can contain isomorphic impurities of Cu, Ni, Co and other elements [7].

Changes in pyrrhotite composition are connected with variable physicochemical conditions of mineral genesis and cause different structural characteristics, mechanical and magnetic properties. In hydrothermal ore deposits pyrrhotite can be found in hexagonal and monoclinic modifications.

The present article describes the study results of pyrrhotite mineralization characteristics in the Chertovo Koryto gold-ore deposit, as well as the chemical composition of pyrrhotites.

## 2. Research methods

To carry out the research core samples were taken from 4 cross-bedding profiles, including two intersecting profiles and one from each opposite cross-bedding. Wells were drilled at full productivity of the ore body with access to the barren area. The drilled depth varies from 150 to 250 m. Core samples were selected thoroughly at intervals from 10 to 50 cm. Firstly, the core samples were studied macroscopically, and samples containing sulphide mineralization, including pyrrhotite, were selected. Then, the polished sections were made for the mineral-graphic study and implementation of point-counter X-ray fluorescence analysis. The polarizing microscope Zeiss Imager A2m was used to carry out the optical study. The chemical composition was studied at the X-ray fluorescence microscope XGT-7200. 184 point-counter measurements were carried out.

## 3. Geological structure of deposit

This deposit is located in the north of Patom upland within the Big Patom river basin. The ore deposit was formed in the early Proterozoic carbonaceous terrigenous slates of Mikhailovskoe suite. The suite



embraces metasomatic rocks of beresite-propylite formation with vein-disseminated sulfide-quartz mineralization. Sulfides occur rarely in quartz veins and veinlets. Pyrite, arsenopyrite, pirhottite are predominant. Galena, sphalerite, chalcopyrite occur as insignificant impurities. Free gold dominates in quartz [8, 9].

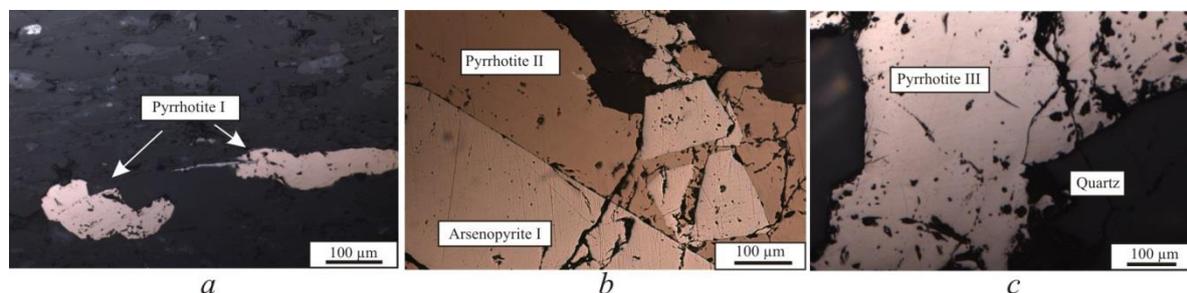
#### 4. Results and discussion

Pyrrhotite is represented by three generations. The generations are separated according to the polishing characteristics, morphology of aggregates, and paragenetic mineral associations.

Pyrrhotite I forms "striates" parallel to the foliation of carbonaceous shales (fig. 1a). It has a eugranitic internal structure. "Striates" size varies in the range of 0.1...5 mm. Usually it has a trace of polishing in form of cavities. The concentrations of main mineralizing elements vary in the following range: Fe – 46.61...48.28 at.%, S – 50.69...53.24 at.%. Copper is found in several samples (0.1; 0.12; 0.14, and 0.28 wt.%). The chemical composition of pyrrhotite corresponds to hexagonal pyrrhotite modification (table 1, fig. 2).

Pyrrhotite II has a compact granular texture with thin quartz-carbonate veinlets (fig. 1b; fig. 2). The iron content varies within the range of 46.64...48.16 at.%, the sulfur content – 50.15...53.52 at.%. Nickel is found among impurities (0.01...1.44 wt.%). Pyrrhotite II includes both monoclinic and hexagonal modifications. The number of the first modification predominates (table 1, fig. 2).

Pyrrhotite III occurs as pocket segregations of various sizes in relatively thick (up to several meters) quartz-carbonate veins (fig 1c). It is polished better than the first two generations without cavities. It is characterized by eugranitic texture and has a nonstoichiometric composition: Fe – 46.45...48.34 at.%, S – 50.54...53.33 at.%. The mineral composition indicates nickel in the amount of 0.01...0.29 wt.%. Pyrrhotite III is characterized by the predomination of monoclinic modification (table 1, fig. 2).



**Figure 1.** Pyrrhotite mineralization in the Chertovo Koryto deposit: a) pyrrhotite I in the form of "stringers" in terrigenous carbonaceous rocks, b) pyrrhotite II in combination with arsenopyrite I in thin quartz-carbonate veinlet, c) pyrrhotite III in quartz-carbonate vein

**Table 1.** Chemical composition of pyrrhotites in the Chertovo Koryto deposit

Generations	Fe, at. %	Ni, wt. %	Cu, wt. %	Fe, at. %	
				Monoclinic	Hexagonal
Pyrrhotite I	46.61...48.28	0.01...0.94	traces	46.61...46.97	47.07...48.28
	47.419 (93)	0.284		46.769 (21)	47.609 (72)
Pyrrhotite II	46.64...48.16	0.0...1.44	0	46.64...47.0	47.07...48.16
	47.323 (41)	0.318		46.838 (25)	47.502 (16)
Pyrrhotite III	46.45...48.34	0.0...0.29	traces	46.45...47.0	47.03...48.34
	47.597 (50)	0.1		46.802 (38)	47.325 (12)

Note: Nominator shows the value interval, denominator shows an average value. Number of samples is given in brackets.

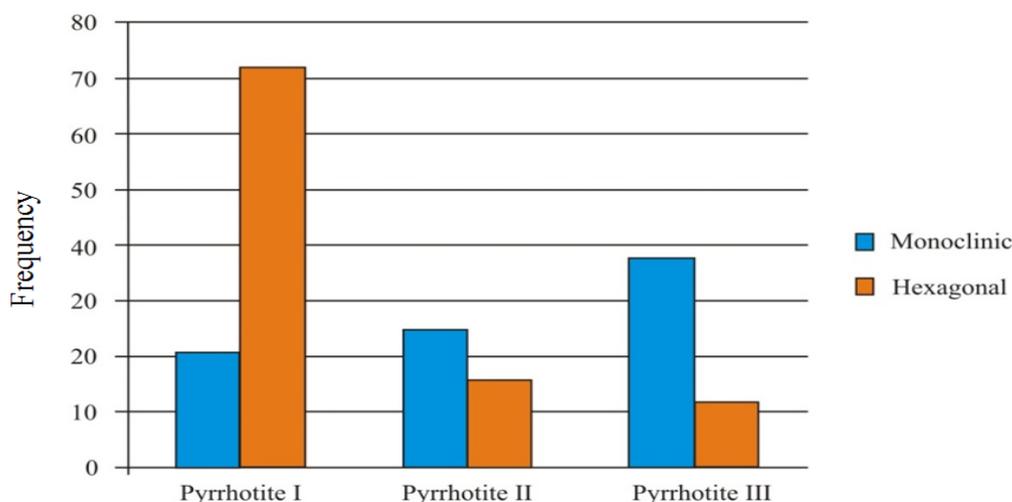


Figure 2. Histogram of frequency of pyrrhotite modifications in various generations (based on the table data)

## 5. Discussion and conclusion

During the research, it was found that in the Chertovo Koryto deposit pyrrhotite is represented by three generations, distinguished by the polishing, morphology of aggregates, paragenetic mineral associations and a range of impurity elements. Generations of pyrrhotines are distributed equally in the ore body. Pyrrhotite I occurs throughout the ore deposit both in the ore and non-ore intervals. Pyrrhotite II and III occur in the central part of the ore body, where rich concentrations of gold intervals are located. All three pyrrhotites are characterized by similar iron content, but different nickel content. The highest nickel content was found in pyrrhotites of I and II generations in the amount of 0.284 and 0.318 wt.%. The presence of nickel indicates textural deformations in sulfide structure. Hexagonal and monoclinic modifications are found in pyrrhotites of all generations (fig. 2). However, the amount of monoclinic modification increases from early to late generation.

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