УДК 553.411.071

MANIFESTATION OF COPPER-PORPHYRY-TYPE AND GOLD-SULFIDE-QUARTZ GOLD DEPOSITS IN THE MAGNETIC FIELD

Федоров В. Г., аспирант гр. А3-71, I курс
Научный руководитель: Колмаков Ю. В., д-р. геол.-минерал. наук, доцент
Национальный исследовательский Томский политехнический университет
English language supervisor: Болсуновская Л. М., канд. фил. наук, доцент
Томск

The gold mining industry is one of the most important strategic areas of industry and economy of any modern country, including Russia.

Gold reserves form the country's gold and foreign exchange fund, which can be used both to preserve existing assets and to increase them through investment. Gold is also actively used in various industries due to its many unique physical and chemical properties. The main industrial consumers of gold include jewelry, the transport sector, chemical and petrochemical production, modern nanotechnology, telecommunications, the manufacture of measuring equipment, the energy industry, the aerospace industry, medicine and, this is not a complete list of areas in which this precious metal is in demand.

From the above it follows that it is impossible to overestimate the importance of gold for the economic stability and productive potential of the country. Consequently, the relevance of the search, evaluation of new and additional exploration of already known and developed gold deposits is very high.

It is known that the volume of global gold mining in 2022 increased slightly (including in Russia) [1].

At the moment, according to preliminary data, Russia ranks 2nd in the ranking of gold-mining countries in the world, only slightly behind China, which has significantly increased the pace of gold mining since 2021 and displaced Russia from first place [1].

The main sources of the country's precious metal include gold deposits of the copper-porphyry type in the Far East (Malmyzhskoye, Ponisky area, etc.) and deposits of the gold-sulfide-quartz type in the Krasnoyarsk Territory (deposits of the Yenisei Ridge). Consequently, deposits of this type are of great interest for prospecting and additional exploration.

One of the main tools at the first stages of geological exploration for searching for deposits of these types is an areal survey of physical fields. The presence of ferromagnets (magnetite, pyrrhotite) in the composition of rocks of productive mineralized zones leads to their anomalous manifestation in the magnetic field and, as a consequence, to the widespread use of magnetic prospecting to search for them. Porphyry copper deposits with vein-disseminated ores are the main sources of gold and copper - about 62% of world production. Deposits of this type are usually large and have a complex multi-metal composition of ores. Deposits of this type also include the Poniysky area, located in the Komsomolsky district of the Khabarovsk Territory. The Mednoye (shown in Figure 1), Olkhovoe, Gribnoye, Borkhi Tonkaya ore occurrences are associated with porphyry intrusions of quartz diorite porphyry [2].

When studying samples of quartz diorite porphyry, which are associated with gold-copper mineralization, veinlet magnetite mineralization was noted, the intensity of which increased in connection with pre-ore carbonate-albite-mica metasomatites. Conventionally, within the development areas of these metasomatic rocks, two zones were identified: the rear zone with the predominant development of albite mineralization and the front zone with a high content of magnetite. The second rocks have a particularly high magnetic susceptibility up to 80000 * 10-5 units SI. This made it possible to successfully identify dike bodies of quartz diorite porphyry by anomalies in the increment of the magnetic induction vector module ΔT (up to 900 nTl) against the background of a quiet magnetic field corresponding to the practically non-magnetic terrigenous sedimentary deposits of the Gornoprotok suite [2]. Ore bodies gravitate more towards the most magnetic areas of the frontal zones of carbonate-albite-mica metasomatic rocks (Fig. 1).

The development of later pyrite-chalcopyrite mineralization with gold in quartz diorite-porphyries and, especially, in magnetite carbonate-albite-mica metasomatites led to a significant decrease in their magnetic susceptibility. This is due to the replacement of magnetite by sulfide paragenesis. In this regard, ore intervals are characterized by extremely high heterogeneity in magnetic susceptibility and a general decrease in ΔT values to 100 and even to a few tens of nTl.

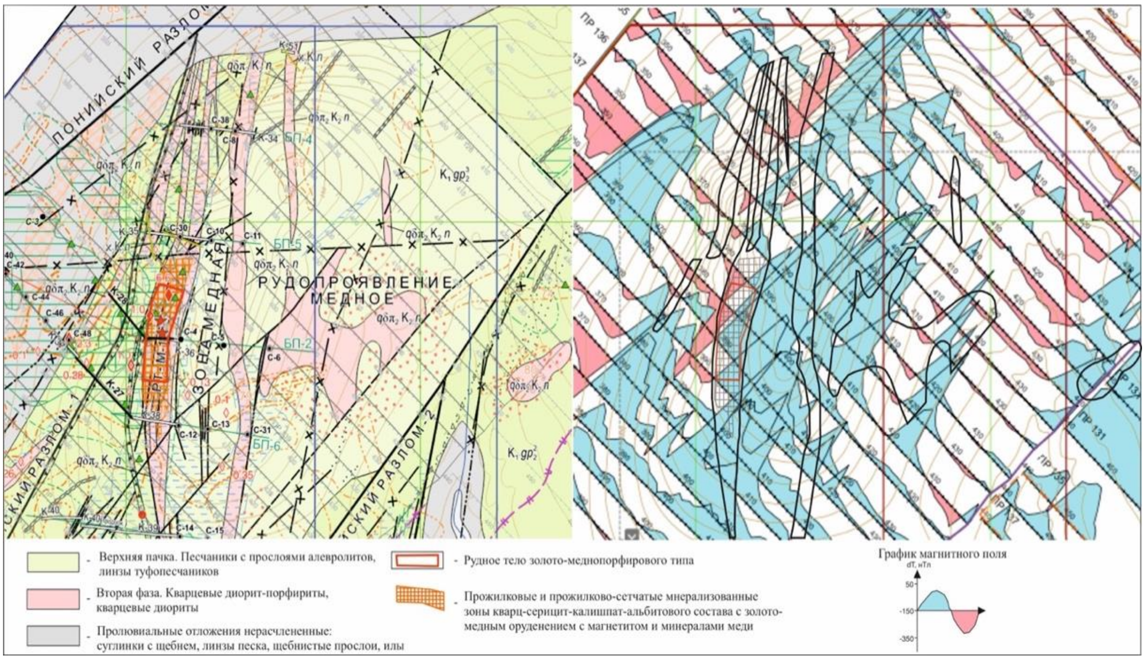

Figure 1. Fragments of a schematic geological map and ΔT graph map with the M-1 ore body of the Mednaya zone [2]

Thus, the peculiarities of the distribution of magnetite mineralization in the products of different stages of mineralization development led to its natural manifestation in the magnetic field.

Gold-sulfide deposits of the veinlet-disseminated type occur in sedimentary and volcanic-sedimentary rocks. Gold in them is associated mainly with sulfides (pyrite, arsenopyrite) and a significant part of it is in finely dispersed form, which complicates the process of their development and, until recently, their exploitation was restrained. But with the development of technology, there has been a significant leap in the exploration and production of gold in deposits of this type, due to the significant number of large-scale objects among them, some of which are in the Yenisei Ridge of the Krasnoyarsk Territory.

One of such deposits is Blagodatnoye, using the example of which the distribution of pyrrhotite mineralization and its manifestation in a magnetic field will be considered.

Here, the amplitudes of magnetic anomalies in the ore zone consistently decrease from 500 to 80 nTl against the background of non-magnetic host rocks. The area with the highest amplitude anomaly on its northwestern flank directly borders the anomalous area (Figure 2). Magnetic heterogeneity can also be traced at the deep horizons of the deposit. In the direction of dip of the ore bodies, an increase in the magnetic susceptibility (χ) of the rocks is observed. Gold mineralization is concentrated in ores with anomalous χ, but not in the most magnetic ones [3].

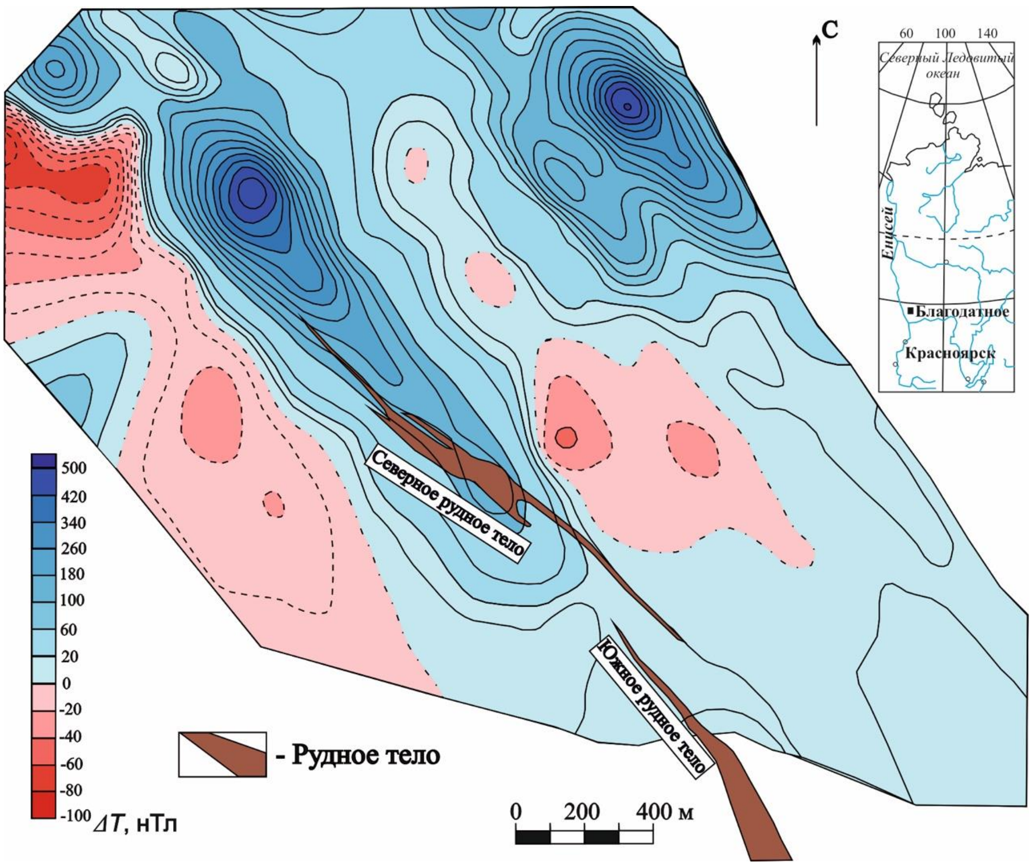

Figure 2. ΔT graph map with the ore bodies of the Blagodatnoye gold deposit [4]

The deposit contains monoclinic and hexagonal pyrrhotites (with a wide range of Fe/S ratios in both), the formation of which occurs under different physicochemical conditions. At the same time, monoclinic pyrrhotites have magnetic properties that vary depending on their composition, hexagonal ones do not, or very weak ones, again depending on the composition [3].

Temperature in the Fe-S-O-H2O system is the most important factor in phase equilibrium in pyrite-pyrrhotite paragenesis. An increase in S/Fe in pyrite is directly related to an increase in its share in the pyrite-pyrrhotite paragenesis, which leads to a decrease in χ of the latter. A regular increase in χ of ores and wall rocks and a decrease in the stoichiometric S/Fe ratio in pyrite is also observed along the dip of ore bodies throughout the ore-bearing zone. In the northern, more magnetic ore body, the average S/Fe value of pyrites (1.842) is significantly lower than the average value of the same ratio (1.998) for the less magnetic southern ore body [3]. In this regard, the increase in χ and the amplitude of the ΔT anomaly in the northwestern part of the ore-bearing zone is interpreted as a deepening of the level of its erosional cut.

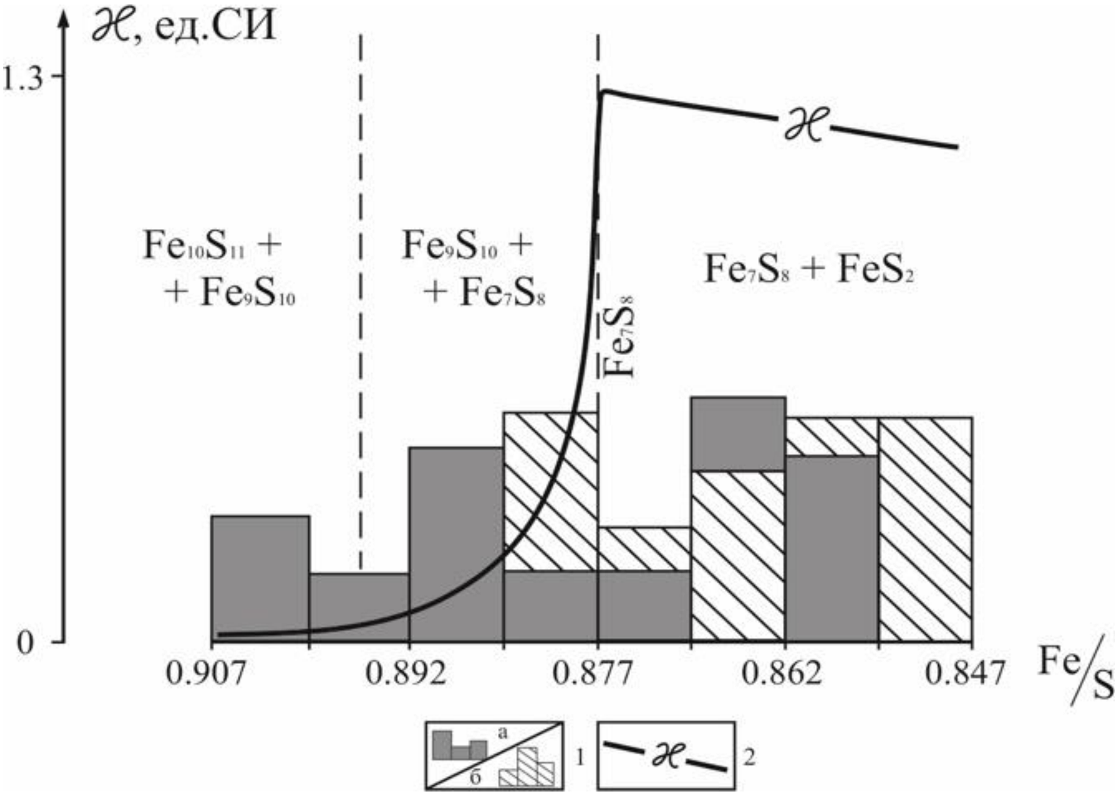

Figure 3. Chemical composition of pyrrhotites from ore bodies of the Blagodatnoye deposit, phase relationships in the Fe-S system and magnetic susceptibility of natural pyrrhotites.
1 – pyrrhotines of the northern (a) and southern (b) ore bodies; 2 – schematic graph of the magnetic susceptibility of pyrrhotites [3]

With increasing temperature and in the composition of pyrrhotite itself, the proportion of the pyrite phase decreased, and it approached the stoichiometrically “pure” monoclinic pyrrhotite Fe_7S_8 - its maximum magnetic phase. Where the maximum temperature was reached, non-magnetic hexagonal pyrrhotite crystallized, which explains the close connection of the magnetic region itself with the non-magnetic one.

Transportation of gold in ore-bearing solutions with sulfide sulfur is carried out in complex compounds such as $Au(HS)_0$ and $Au(HS)_2$. The concentration of gold in weakly magnetic ores is caused by the massive binding of sulfide sulfur in pyrite during their formation, destabilization of complex compounds and precipitation of gold in metallic form [5].

Thus, using the example of large deposits of two common types (porphyry copper and gold-sulfide), the natural localization of ore gold in mineralized blocks with a zonal distribution of ferromagnets manifested in a magnetic field is shown.

Список литературы:

1. Золото и технологии// Главная// Итоги// Аналитика// Золотодобывающая промышленность России: текущее состояние и перспективы. URL: https://zolteh.ru/results/zolotodobyvayushchaya-promyshlennost-rossii-tekushchee-sostoyanie-i-perspektiv/
2. Федоров, В. Г. Геофизические признаки оруденения золото-медно-порфирового типа на Понийском участке Приамурской вулкано-плутонической зоны (Хабаровский Край) // XXIV Уральская молодежная научная школа по геофизике: сборник научных материалов, Пермь, 20-24 Марта 2023. – Пермь: ГИ УрО РАН, 2023 – С. 256-260
3. Колмаков, Ю. В. Пирротиновая минерализация золоторудных месторождений Енисейского кряжа: состав, свойства и проявление в магнитном поле / Ю.В. Колмаков, А.Ф. Лазарев, В. Г. Федоров // Годичное собрание РМО «Минералого-геохимические исследования для решения проблем петро- и рудогенеза, выявления новых видов минерального сырья и их рационального использования. Федоровская сессия 2023: сборник научных материалов, Санкт-Петербург, 10-12 октября. – Санкт-Петербург: РАН, 2023 С. 124-125
4. Колмаков, Ю. В. Реконструкция петрофизической зональности золоторудного месторождения Благодатное в Енисейском кряже: геодинамический и физико-химический аспекты / Ю. В. Колмаков, А. М. Сазонов // Литосфера, 2022, том 22, №5, С. 667-693
5. Пальянова Г. А. Геохимическая подвижность Au и Ag в условиях гидротермального переноса и отложения (термоднамическое моделирование) / Г. А. Пальянова, Г. Р. Колонин // Геохимия. – 2007.№ 8. – С. 814-828.