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Research Article

FEATURES OF GEOPHYSICAL AND GEOLOGICAL CHARACTERISTICS OF GOLD ORE DEPOSITS OF THE ZIAETDIN MOUNTAINS (SOUTHERN TIEN SHAN, UZBEKISTAN)

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ABSTRACT
The article discusses the main geophysical methods used in the search for gold ore deposits. The applied aspects of using a complex of geophysical methods in conditions of high contrast of the physical properties of the host rocks are considered. The self-potential (SP) method was applied to delineate zones of sulfide-related gold mineralization.

Keywords: *Physical-Geological Model, Gold Ore Deposits, Gold-Sulfide-Quartz Deposits, Anomalies, Geophysical Fields, Self-Potential (SP).*

INTRODUCTION
The Ziaetdin Mountains belong to the South Tien Shan fold belt. More than 100 gold ore objects (deposits, occurrences, and mineralization points) have been identified in the Ziaetdin Mountains; they are associated with the Katarmay Formation (Fig. 1). The most important structural element of the ore field is the Karakutan fault zone, represented by a series of long latitudinal and sublatitudinal faults forming two major subparallel zones of fracturing and quartzification. Almost all known gold deposits and occurrences within the ore field are confined to these structures. The most significant deposits in terms of scale, including Karakutan and Beshkuduk, are localized in the eastern part of the ore-bearing zone. Gold mineralization is represented by a quartz-moderately sulfide gold ore formation.

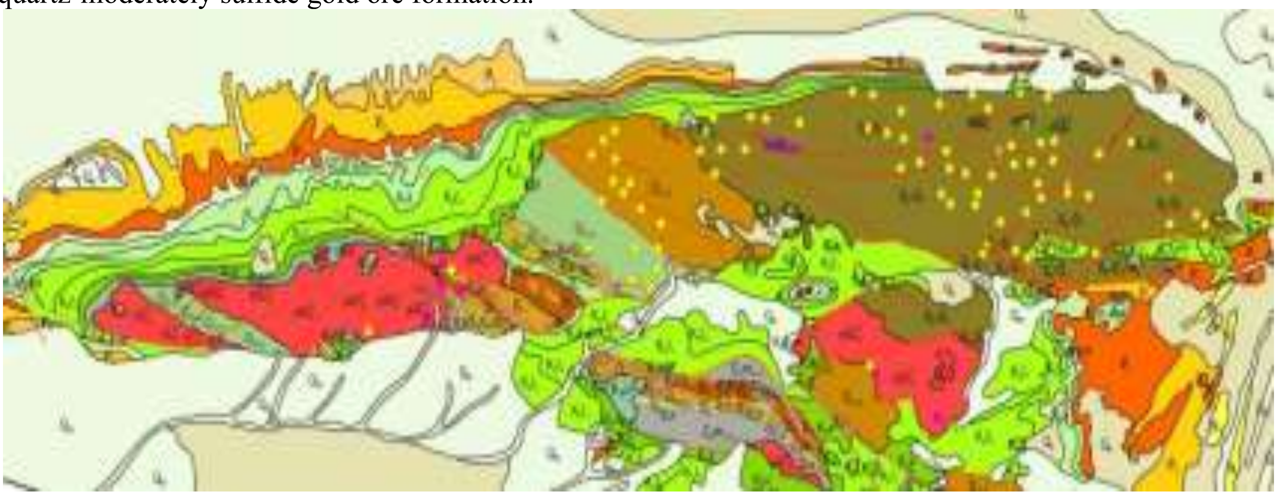

Figure 1: Fragment of the distribution map of gold ore objects of the Ziaetdin Mountains (based on a geological map at a scale of 1:200,000).

A physical–geological model is a generalized but subjective representation of a real geological object that includes information on physical properties, morphology, bedding elements, lithological and structural features, geodynamics, age, and geophysical fields (Bondarenko et al., 2023; Gladkov et al, 2010).
A geological-geophysical model is a specific case of a physical-geological model, in which data on geological structure (structure and composition) and physical fields (gravity, magnetic, seismic, etc.) are considered.

MATERIALS AND METHODS

Gold ore deposits are among the most significant objects of the global mineral resource base. In recent decades, considerable attention has been paid to the development of geological-geophysical models that integrate lithological-structural, mineralogical, petrophysical, and geophysical data (Dentith et al., 2014).
The main geological-industrial types of endogenous gold deposits include gold-sulfide-quartz, gold-sulfide (epithermal), gold-quartz, gold-porphyry, and gold-skarn deposits, each characterized by specific geological and geophysical features (Nevolin et al., 2002; Smirnov, 1980).
Gold-sulfide-quartz deposits localized in black shale formations represent promising exploration targets. However, the high density and magnetic susceptibility of these rocks create difficulties in anomaly identification; examples include the gold ore objects of the Ziaetdin ore field. Therefore, the key direction is the use of an integrated complex of geophysical methods.
Based on the generalization and analysis of data from published works by numerous authors, a comparative table of geophysical methods was compiled, reflecting their exploration capabilities and limitations (Table 1) (Vollgger et al., 2016). Typical anomaly ranges were identified: for magnetometry ±800 nT, for induced polarization (IP) 8-25 mV/V, for self-potential (SP) up to 300 mV, and for gravimetry ±1 mGal.

Table 1: Comparative table of geophysical methods reflecting their exploration capabilities

Method	Anomaly range	Geological interpretation	Examples of objects
Magnetic survey	+200 to +800 nT; zones of decrease down to -50 nT	Pyrrhotite lenses, magnetite dikes; zones of demagnetization in beresites	Muruntau (Uzbekistan), Kumtor (Kyrgyzstan)
Gravimetry	+0.3–1.2 mGal; negative -0.1 to –0. 3 mGal	Positive anomalies - sulfidation; negative anomalies - zones of fracturing and carbonation	Ziaetdin ore field (Uzbekistan)
Induced polarization (IP) method	Chargeability 8-25 mV/V; decrease in resistivity to 1-30 Ω·m	Zones of pyritization and arsenopyritization	Olimpiada (Russia), Ashanti (Ghana)
Self-potential (SP) method	+50-300 mV along faults and veins	Zones of oxidized sulfides (goethite, limonite)	Sukhoi Log (Russia)
Electromagnetic methods	Low-resistivity zones 10-50 Ω·m (depth 200-500 m)	Metasomatites, conductive ore bodies	Bambui (China)

The data presented in Table 1 show that maximum efficiency is achieved through the integrated application of magnetic surveys and electrical prospecting methods, including IP and SP Nikitin et al., 2012). Magnetic surveys make it possible to trace magnetite and pyrrhotite bodies, while IP identifies zones of sulfide mineralization (Lukyanov et al., 1984). The SP method provides near-surface indicators, especially in oxidation zones. Gravimetry and electromagnetic methods complement the understanding of deep geological structure, while seismic surveys identify zones of increased fracturing and metasomatism. Particular emphasis is placed on demagnetized zones (beresitization, carbonation), where magnetic susceptibility decreases and gold mineralization is often localized.
Under conditions of a complex geophysical environment, the most informative methods are IP and SP, supported by magnetometry and gravimetry, which ensure increased accuracy and reduced risk in gold prospecting.

When considering the features of the self-potential field of the Zirabulak-Ziaetdin region, which includes the Ziaetdin Mountains, a map of self-potential anomalies (U_{SP}) was constructed (Fig. 2).

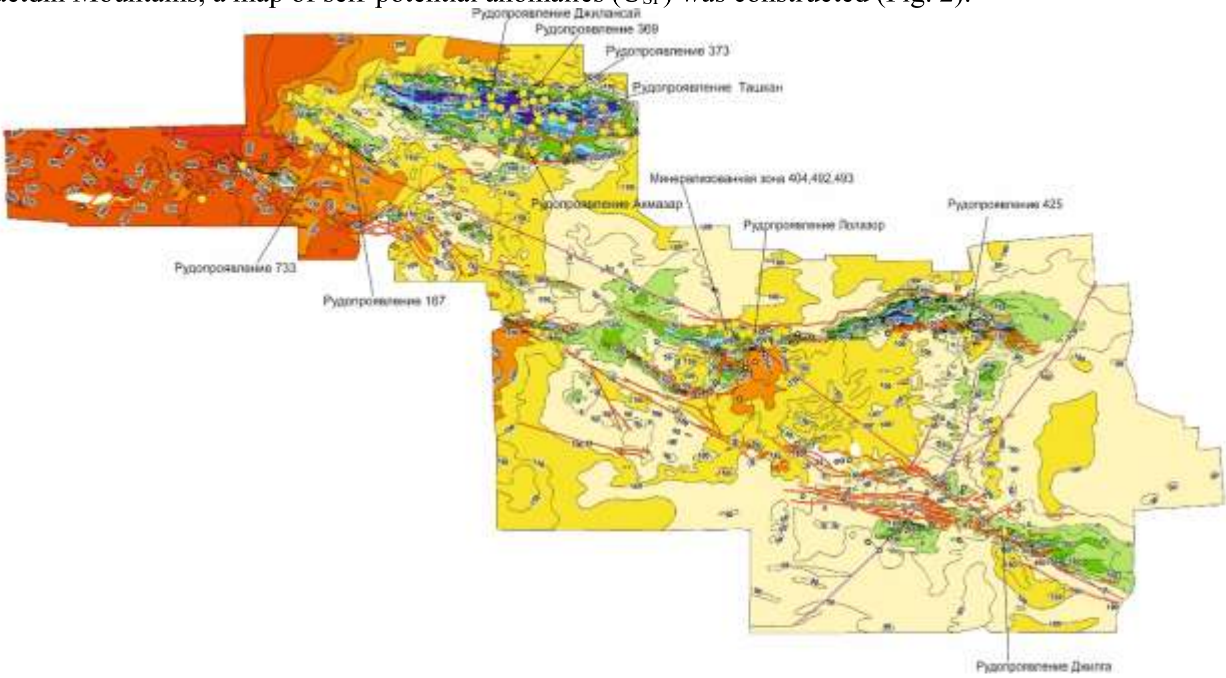

Figure 2: Map of self-potential (SP) isolines of the Zirabulak-Ziaetdin ore district with superimposed faults and gold ore objects.

The self-potential field is characterized by a wide range of USP values (from -700 to +500 mV). A number of negative anomalous zones and local anomalies are distinguished, spatially associated with certain lithological complexes characterized by low electrical resistivity, as well as with fault zones where rocks have undergone intense fracturing and hydrothermal alteration (quartzification, potassium metasomatism, etc.) accompanied by sulfidation, which led to a sharp increase in electrical conductivity (Sadikova et al., 2022).
Gold deposits and occurrences are predominantly located in the marginal parts of fault zones, within areas of gradients of self-potential anomalies. This is explained by the fact that the localization of gold and associated mineralization occurs within fracture halos around permeable channels. The highest positive SP values (+200 to +300 mV and higher) are characteristic of carbonate rocks, granitoid intrusions, and other formations. Zones of tectonic disturbances accompanied by hydrothermal processes (sulfidation, carbonization, etc.) are traced by intense negative SP anomalies (from -200 to -400 mV).
One of the most pronounced negative zones is identified in the Ziaetdin Mountains and covers the area of distribution of terrigenous-volcanogenic rocks with carbonate horizons of the lower and middle subformations of the Katarmay Formation, often containing carbonaceous matter, pyrite, and other sulfides in noticeable (1-2%) amounts. Fault tectonics is widely developed here, accompanied by carbonate, quartz-tourmaline, quartz-sericite, and other metasomatites. Areas of the most intense fracturing and hydrothermal alteration are marked by local minima reaching -500 to -600 mV. Such areas, where minimum values are observed, are the most favorable for ore localization.

RESULTS AND DISCUSSION

Typical ranges of anomalies of the gold-sulfide-quartz type of deposits have been identified: ±800 nT for the magnetometric method, 8-25 mV/V for IP, up to 300 mV for SP, and ± 1 mGal for gravimetry. The self-potential field is characterized by a wide range of changes in the U_{SP} potential (from -700 to +500 mV), is characterized by high contrast and reflects the influence of lithology and discontinuous tectonics. Negative SP anomalies are associated with zones of crushing and hydrothermal changes in rocks with increased electrical conductivity. Gold ore objects are localized mainly in the marginal parts of faults, in zones of elevated gradients of the SP potential, which makes such areas the most promising for mineralization.

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