Relationship of copper-molybdenum and gold minering with magmatism

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Abstract. In the investigated deposits, a combination of skarn and hydrothermal mineralization has been identified. Specific facies within intrusive complexes align with distinct postmagmatic formations. Skarn-magnetite formations are intricately linked with the granitoid complex of the initial phase, while hydrothermal mineralization has a genetic connection to the subsequent phase of magmatism, characterized by minor intrusions of granodiorite porphyry. A distinctive zonal structure of individual facies, such as quartz-sericite-chlorite metasomatites, is observed around these granodiorite porphyry intrusions. The manifestation of rock wall metasomatism, as well as copper-molybdenum and gold ore mineralization, closely corresponds to the extent of the granodiorite-porphyry occurrences. This correlation highlights the intimate relationship between the scale of mineralization and the manifestation of granodiorite-porphyry, emphasizing the role of specific magmatic phases in the formation of skarn and hydrothermal deposits. The findings contribute to our understanding of the geological processes governing the development of diverse mineralization types within these deposits.

1 Introduction

Mineral resources play a pivotal role in advancing the productive forces of numerous countries globally. Geology and exploration, recognized as structure-forming branches of the national economy, are tasked with the identification, exploration, and preparation for the development of mineral deposits that hold industrial significance [1-3].

The intricate processes of geology and exploration are essential for uncovering and assessing valuable mineral resources, laying the foundation for sustainable economic development. These disciplines contribute significantly to a nation's industrial infrastructure by identifying and characterizing mineral deposits that can be harnessed for various applications, including energy production, manufacturing, and technological advancements.

As structure-forming branches, geology and exploration provide the essential groundwork necessary for informed decision-making in resource utilization. The accurate identification

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and evaluation of mineral deposits enable countries to optimize their resource management strategies, ensuring the responsible and efficient extraction of minerals that drive economic growth and technological progress. In essence, these fields are indispensable in shaping the trajectory of a nation's development by unlocking the wealth contained within its geological formations.

The epoch of easily accessible, large deposits near the Earth's surface in numerous regions across the globe is gradually waning. Presently, geologists and miners are redirecting their focus towards submerged horizons that exhibit favorable conditions for hosting industrial mineralization. This shift transforms the search, exploration, and production of mineral resources into a progressively labor- and capital-intensive undertaking [4-6].

The exploration and extraction of submerged mineral resources present a new frontier for the industry, demanding innovative technologies and methodologies. As traditional surface deposits become less prevalent, the industry's attention turns to the challenges and opportunities posed by underwater mineralization. This paradigm shift necessitates substantial investments in both labor and capital to develop advanced exploration techniques, deep-sea mining technologies, and sustainable environmental practices.

The transition to exploring submerged horizons underscores the industry's adaptability in the face of evolving geological challenges. As mining ventures delve into deeper and more remote locations, the need for cutting-edge technology and responsible resource management becomes increasingly paramount. This transformative phase reflects the industry's commitment to meeting the growing global demand for minerals while embracing the complexities of extracting resources from submerged environments.

2 Materials and methods

Under such conditions, increasing the efficiency of geological exploration is possible by improving the theoretical and methodological foundations of the conditions for the formation of endogenous industrial mineralization through the use of a set of new innovative technologies, analysis of the localization conditions of various types and industrial-genetic types of minerals.

The study of hydrothermal mineralization manifested in the Dalny copper-molybdenum deposit (Kuraminsky ridge) and in gold deposits - Karakutan, Beshkuduk (Ziyaetdinsky ridge), Marjanbulak, Sarmich, Zarmitan and Guzhumsay (Nurata ridge-molybdenum) with a favorable combination of magmatic, metasomatic, lithological, geological-structural and other factors [5, 7-9].

Within ore fields, the presence of deep, enduring faults is notable, manifesting as a series of intricate and extensively branching fracture zones. These fault zones are characterized by brecciations, alterations in the host rocks, dyke bodies, and eruption centers. The rocks within these fault zones exhibit high levels of fracturing, creating a conducive environment for the localization of mineralization [8, 10].

The complex nature of these fault zones suggests a dynamic geological history, with various processes contributing to the formation of favorable conditions for mineralization. The branching fracture zones and brecciations indicate the past movements and stresses that have influenced the structural integrity of the rocks. Additionally, alterations in the host rocks signify changes brought about by geological forces, possibly influencing the chemical composition and creating conditions suitable for the deposition of minerals.

The presence of dyke bodies and eruption centers further points to the dynamic geological processes within these fault zones. Such features could indicate the influence of magmatic activity and volcanic processes, contributing to the mineralization potential of the region. The characterization of these deep, long-lived faults provides valuable insights for geologists and miners seeking to understand and explore the mineralization patterns within ore fields.

Below is a brief description of the results of our work on the study of magmatic search criteria for copper-molybdenum and gold ore bodies, taking into account the work carried out by previous researchers.

3 Results and discussion

After the formation of the earth's crust, it itself began to serve as a source for the formation of magma. Basalt magma is formed due to the basalt layer, and granite magma is formed due to the granite-gneiss layer (Figure 1).

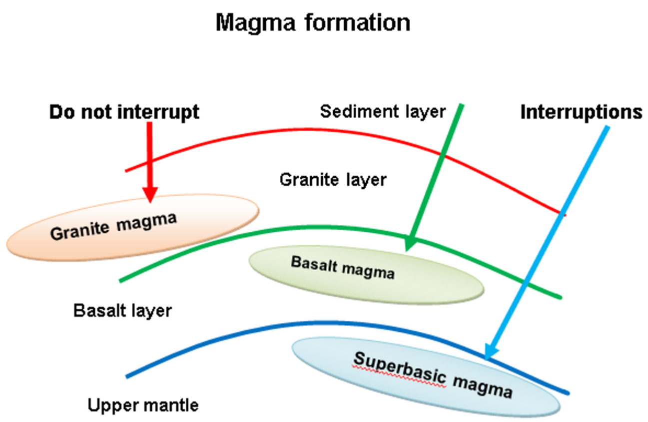

Fig. 1. Formation of magma.

Magmatism is considered a factor providing not only placement, but also the emergence of endogenous copper-molybdenum, gold and other formations. In light of this, the connection of copper-molybdenum and gold ore formations with magmatic complexes of Uzbekistan is considered.

The opinions of geologists who conducted research in Central Asia do not agree on the connection of postmagmatic formations with intrusive manifestations. The relationship of endogenous mineralization with intrusions was pointed out in their works by Kh.M. Abdullaev [1], Kh.Khamrabaev [2], A Aizenshtadt et al. [3] and others.

Diorite - granodiorite - granite petrochemical series, according to Kh.M. Abdullaev [1], are associated with skarn - magnetite, skarn - scheelite, skarn - molybdenum, skarn - gold and possibly some quartz - sulfide deposits. By the time of formation, these deposits belong to the batholithic stage of the petrometallogenic process.

A.V. Korolev and V.G. Gorkovets (1964), on the basis of structural - metallogenic analysis, characterized the Paleozoic structures of Central Asia and the Urals as large gold-bearing structures, and they also noted the important role of Hercynian magmatism in the formation of gold deposits.

When zoning gold-bearing areas in Central Asia, IA Aizenstadt [4] confirmed the ideas of Kh.M. Abdullaev and attributed gold mineralization to the middle stage of geosyncline formation, showing that it is associated with large granitoid intrusive complexes of the Hercynian magmatism cycle.

Describing the main features of metallogeny in Uzbekistan, indicate that the deposits of ore gold in the Zirabulak - Ziaetdin mountains are associated with II - III, and even later phases of intrusive activity of the Hercynian cycle.

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I.Kh.Khamrabaev [2], conducting research in Western Uzbekistan, indicates that there are spatial and temporal connections of ore occurrences with the Upper Carboniferous complex of granitoids, similarity of types of postmagmatic mineralization established near some intrusions, as well as primary enrichment of granitoid magmas with ore components.

Aizenshtad I.D., Wolfson N.B., Denisov S.A. and Musin R.A. [3] indicated that copper-molybdenum deposits in the Almalyk ore province are genetically related to small stocks of granodiorite porphyry.

Statistical analysis of copper-molybdenum and gold deposits and magmatic occurrences shows that there are spatial, temporal and material connections between them.

The materials we have collected on the Almalyk province confirm the idea of the multiple occurrences of the ore formation process and the genetic relationship of mineralization with certain phases of the intrusive complex:

Certain facies intrusive complexes correspond to certain associated postmagmatic complexes. Skarn-magnetite formations are associated with syenite-diorites of the batholith stage. They formed before the introduction of the final phases of the syenite-diorite complex. This is confirmed by the intersection of garnet skarns by syenite-porphyry and lamprophyre dikes in the Nakpai area. In Kurgashinkan and Dalny, two types of mineralization appeared: skarn and hydrothermal. Skarns were formed at the contact of limestones with syenite-diorites, overlaid by later hydrothermal mineralization.

The most productive metallogeny of the Almalyk province (copper, molybdenum and base metals) manifested itself in a close genetic relationship with small intrusions of porphyry granodiorite. This connection is proved by the following factors: a). All copper-molybdenum deposits of the Almalyk province are spatially associated with small intrusions of granodiorite-porphyry; b). Extensive development around the last hydrothermally altered rocks. Typical vertical and horizontal zonal structure of individual facies of quartz-sericite-chlorite metasomatites. The quartz facies directly border the apophyseal granodiorite porphyry. Which is replaced by quartz-sericite, the outer zone is quartz-chlorite facies (Figure 2); in). Copper mineralization gravitates to the places of occurrence of small intrusions of granodiorite-porphyry (Figure 3); d). The scale of rock wall metasomatism and copper-molybdenum mineralization is closely related to the scale of manifestation of the latter.

In the placement of molybdenum and copper-molybdenum mineralization, granodiorite-porphyry, in addition to a genetic role, also play a structural role. This is reflected in the fact that during the intrusion of grandiorite porphyries, powerful crushing zones were formed in the host rocks, where molybdenum and copper-molybdenum mineralization are confined.

In the Almalyk province, the zoning of the spatial distribution of various types of hydrothermal deposits in relation to the intrusion has been established. Higher-temperature molybdenum (Nodirbek et al.) And copper-molybdenum ore bodies (Kalmakyr, Dalny, Kyz-ata, etc.) directly border porphyry granodiorite, and polymetallic (Kurgashinkan, etc.), gold (Ak-turpak, etc.) deposits are located at some distance from the latter.

A comparative study of the deposit of the Almalyk ore province shows that copper-molybdenum and polymetallic mineralization was carried out from a single source, but localized in various favorable geological and structural conditions.

The genetic relationship between copper-molybdenum and polymetallic deposits is proved by the following facts: a). The same nature of the development of hydrothermally altered rocks in both types of deposits; b). The deposits contain the same hydrothermal minerals, manifested in varying degrees of intensity; in). The main ore minerals - pyrite, chalcopyrite, galena, sphalerite, molybdenite - are noted as copper-molybdenum and polymetallic deposits.

Kh.M. Abdullaev [1] pointed out that the zoning of the location of ore deposits relative to the intrusive massif is one of the most interesting questions of the metallogenic theory.

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According to the study of many provinces of the world, small intrusions and polymetallic deposits are removed from large intrusive massifs at a distance of 1.5-2 to 8-20 km and lie among the roof rocks.

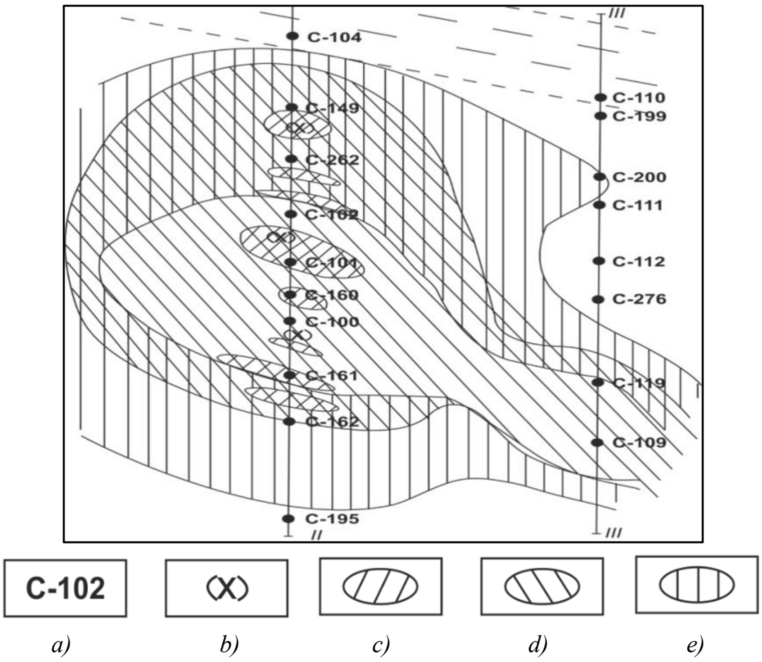


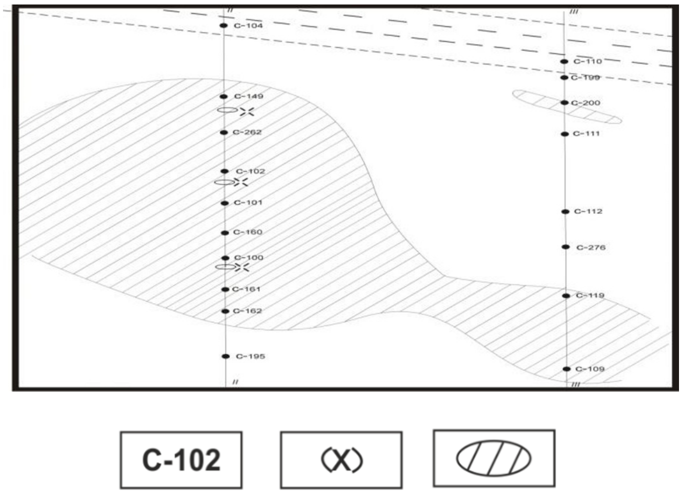
Fig. 2. Development of metasomatic zoning around small porphyry granodiorite stocks: *a* - quartz syenite-diorite and core wells, *b* - apical parts of small stocks of granodiorite porphyry, *c* - medium silicified rocks, *d* - medium sericitized, *e* - medium chloritized rocks.

In Western Uzbekistan, gold ore, gold-silver, uranium, tungsten and other mineralization are associated with intrusions and volcanic formations. Most of the ore bodies are localized in the zone of supply channels of magmatic bodies [5].

The Karakutan ore field (Ziaetdinsky ridge) is located in the northern flank of the Katarmay anticline. Within the limits of the ore field, volcanic rocks and dikes are widely developed, which are part of a granitoid massif not exposed by erosion, located in the nuclear part of the Katarmay anticline. The presence of numerous dikes is characteristic, both in the body of the intrusion and outside it.

Within the Karakutan ore field, two zones of increased fracturing were identified with a size of 1.0 and 1.5 km^2, their strike northeast - 20 °. The relief within the zones is smoothed. The Karakutan field is located within the western zone, and Beshkuduk in the eastern zone. On aerial photographs, they are represented by a zone of increased ring-shaped fracturing. These structures mark non-surface apophyses or stocks of intrusive. The gold ore bodies of Beshkuduk have an oval structure, thus they also confirm the presence of intrusion at the depth of the apophyses.

In Beshkuduk and Karakutan, gold ore mineralization was formed in the over-intrusive zone with a wide development of dike formations of intermediate and felsic composition. They are represented by rich, complex ore bodies in the form of subvertical pillars of stockwork structure, composed of quartz veins and zones of vein mineralization, accompanied by hornfelsed and silicified, albitized, sericitized and chloritized rocks.



a) *b)* *c)*

Fig. 3. Development of copper mineralization at horizon 408 of the Dalniy deposit: *a*) - quartz syenite-diorite and core wells; *b*) - granodiorite-porphyry; *c)* - the area of development of copper mineralization is more than - 0.3% (compiled on the basis of the materials of the geological party).

In the nuclear part of the Katarmai anticline, in our opinion, there is a large granitoid massif. This is supported by the fact of the development of hornfelses and quartz - albite - sericite - chlorite metasomatites [6], which are developed unevenly throughout the Karakutan ore field. The intensity of their changes increases within the Karakutan, Beshkuduk deposits and in other areas. Mineralization predominantly gravitates towards the apical parts (not exposed by erosion) of the productive phases of the granitoid complex (Karakutan, Beshkuduk, etc.) and towards the vent part of volcanoes (Tillatag) [5]. In the Ziaetda Mountains, volcanic rocks are more than 20 km long. Apparently, there were several effusive supply channels here.

We carried out field work in the area of ore occurrence 4 of the Beshkuduk deposit. Parallel dikes of quartz diorites are developed here, small in length, with a northeastern strike. Commercial ore bodies extend parallel to the dikes. We have processed the results of spectrometric and gold-metric and assay analyzes obtained during the exploration of ore occurrence. Areas of gold ore mineralization with trace content and higher than 0.1 ppm have an oval shape, as if repeating the supposed apophyses of granitoids.

The metallogeny of the Zirabulak - Ziaetda Mountains is determined by ore-bearing granitoid intrusions of the hypabyssal depth level. Their distinctive features are a complexly differentiated and diverse structure. The criterion for the potential productivity of such massifs is the focusing of many effusive and intrusive portions on a relatively small area.

The granosyenite complex of the Koshrabad massif (Nurata ridge) is multiphase, moderately alkaline in chemical composition, with approximately equal potassium and sodium contents. According to geophysical data, the Koshrabad granitoid intrusive massif is a laccolith-like body, the base of which lies at a depth of 3.5-5 km, its root part is located on the meridian of the Guzhumsay stream. Intrusions of the productive phase of the granosyenite complex are located here, with which hydrothermal mineralization is genetically related [2]. Hydrothermal solutions rose through supply channels and spread along faults.

4 Conclusions

The ore bodies of Gujumsay are brought together in the form of a bundle. In plan, they form the shape of an elongated ellipse. In our opinion, this once again confirms the data of geophysicists who indicated that the supply channel of the laccolithic Koshrabad intrusion is located in the Guzhumsay area. It seems to us that the confinement of Guzhumsai to the supply channel of granosyenites is confirmed by the zonal arrangement of technological types of ores. In Guzhumsay, ores are classified as gold-bearing.

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