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ABSTRACT

Of the dissertation for the degree of Doctor of Science

GENETIC MODELS OF THE FORMATION OF ENDOGENOUS ORE DEPOSITS IN THE JUNCTION ZONE OF MUROVDAG AND AGHDAM ANTICLINORIUMS (LESSER CAUCASUS)

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Applicant:	**Mamoy Ibrahim Mansurov**

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The work was performed at the Department of Mineral Resources of Baku State University, Ministry of Science and Education of the Republic of Azerbaijan.

Scientific consultant: Full member of ANAS, Honored Scientist, Doctor of Geological and Mineralogical Sciences, professor **Vasif Mammad Agha Baba-zadeh**

Official opponents: Doctor of Geology-Mineralogy Science, ANAS reporter member **Talat Nasrulla Kangarli**

Doctor of Geology-Mineralogy Science professor **Vagif Shikhi Gurbanov Qurbanov**

Doctor of Geology-Mineralogy Science professor **Tofig Rashid Ahmadov**

Doctor of Geology-Mineralogy Science **Nizami Najaf Jafarov**

Dissertation council BED 2.21 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at Baku State University, Ministry of Science and Education of the Republic of Azerbaijan

Chairman of the Dissertation council:

Doctor of Geological and Mineralogical Sciences, professor **Bahadir Hasan Galandarov**

Scientific secretary of the Dissertation council:

PhD in Earth Sciences, Associate professor

______________ **Ulkar Ibrahim Karimli**

2520.01

Chairman of the scientific seminar:

Doctor of Geological and Mineralogical Sciences, professor **Shahla Faig**

______________ **Abdullayeva**

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INTRODUCTION

Relevance of the topic. The presented dissertation is the product of the author's 20-year research work in the direction of the study of endogenous ore deposits belonging to different formation types concentrated in the junction zone of the Murovdag and Aghdam anticlinoriums. Information on the study of existing deposits by various researchers is reflected in numerous monographs, scientific articles and reports. Although the conducted studies are devoted to the relation of porphyry copper, pyrite, gold and polymetallic ores with magmatism, the structural factor of the localization of ore deposits, the physico-chemical conditions of mineralization and similar issues, the solution of a number of necessary issues, including the complex use of modern research methods, the problem of building geological and genetic models of deposits has not been solved. At the same time, despite conducting certain scientific and research works on existing noble and non-ferrous metal deposits in the region, the investigation and solution of a number of important geological issues has not been brought to its logical end.

It should be emphasized that although the noble and non-ferrous metal deposits of the region have enough potential resources, the scientific and theoretical justification of the creation of their mineral-raw material base in our republic is an urgent problem waiting to be solved. Therefore, in order to solve the problem, it is very important to study the conditions of formation and location regularities of all known non-ferrous and noble metal deposits in the region, especially to conduct scientific research works with modern methods in the direction of building geological-genetic models of the deposits.

So, in addition to the abovementioned points, taking into account the fact that a number of issues of various endogenous mineralization at the junction of the Murovdag and Aghdam anticlinoriums have not been studied to the end, the development of the predicted criteria for the theoretically justified assessment of the prospects of building geological and genetic models of porphyry copper, copper-polymetallic, copper-pyrite and other genetic-formation type deposits, which were formed in different ore-magmatic systems, shows the relevance of the dissertation.

Research aims and objectives. The main goal of the work is to build geological and genetic models of endogenous ore deposits of ore-magmatic systems formed in the island arc conditions of the junction of Murovdag and Aghdam anticlinoriums in the Middle and Late Jurassic-Early Cretaceous period, and according to this, to develop the scientific basis of the search and prediction of mineral deposits.

The main objectives of the research work include the following:

1) determination of the main regional and local geological factors that provide conditions for spatial and temporal localization of porphyry copper, copper-pyrite and copper-polymetallic deposits and occurrences within the framework of ore-magmatic systems; 2) the genetic or paragenetic relation of mineralization with magmatism, and determining space and time in the general development of the region; 3) assessment of the role of structural and magmatic, mineralogical and geochemical, metasomatic and physico-chemical factors in the ore-magmatic systems of the region and their development; 4) determining structural and morphological characteristics of ore masses, their internal structure and their relation with the host rocks; 5) determining the zonation of metasomatites belonging to different formation types, studying the place of mineralization in the metasomatic column and its industrial importance; 6) characterization of geochemical characteristics of metasomatosis around the ore and behavioral characteristics of the main ore components; 7) study of gradual development of ore deposition, mineral composition and mineral types of ores, paragenetic mineral associations and typomorphic features; 8) study of the geochemical properties of the main ore and its accompanying components, determining the mutual correlation between them; 9) revealing physico-chemical conditions of ore deposition by thermobarogeochemical studies; 10) development of the geological-genetic model of the formation of ore-magmatic systems based on

geological and physico-chemical criteria; 11) development of the scientific basis of the main directions of the future geological-research works and predicted-research criteria.

Factical materials and research methods. The basis of the dissertation work is the results of personal research of the actual materials, which were collected in fields during 20 years of scientific work by the author, in the laboratory with modern optical-microscopic and mineragraphic, mineralogical-geochemical and physico-chemical methods. PhD candidate studied the magmatic and geological-structural features of the formation of endogenous ore deposits at the junction of the Murovdag and Aghdam anticlinoriums of the Lesser Caucasus island arc zone on the topics of "Strategic types of mineral raw materials – geological features, conditions of formation and complex assimilation and use" carried out at the Department "Geology of minerals" of BSU and "Prediction of mineral resources of structural-formation zones of the Lesser Caucasus using complex aerospace, geological-geophysical and geomorphological studies" carried out at Complex geological and geophysical studies ETL, as well as within the framework of SRDF USA (state registration No. SCI-010 000-05; 2005-2007), SCOPES grant programs (IZ Se 7320-128324; 2011-2013) since 2001.

Quantitative analysis of rocks for the main chemical components and ore-forming elements (Cu, Mo, Zn, Pb, Se, Te, etc.), analytical data on the composition of minerals and ore-forming fluids – thermobarogeochemical analysis were determined by modern methods in the leading laboratories of USGS Geological Service of USA (Denver), SOS Mineral Services UK LTD (Ontario, Canada), Turkey (Izmir) and Georgia (KIMS, Tbilisi). More than 100 thin sections and polished sections have been studied. X-ray analysis of minerals was carried out at the Department of the Physico-chemical Analysis of the Institute of Inorganic Chemistry and Catalysis of ANAS on a D2 PHASER xnd automatic diffractometer. At the same time, the results of more than 2000 chemical, spectral and sample analyzes conducted on the main components of rocks and ores and archive materials of the National Geological Exploration Service and foreign companies were used. Processing of pertochemical and geochemical data was carried out based on the creation of a primary database. Geochemical data on the main components were carried out by the method of factor analysis in the STATISTICA-10 program. SPSS statistical package was used for the factor analysis. The statistical processing of primary materials based on the results of spectral analysis of surrounding rocks and ores was carried out by the “MINITAB-16” program. “Arc GIS” and “Corel Draw X6” computer software packages were used in the processing of graphic materials.

So, as it can be seen, the presented dissertation was successfully completed as a result of scientific analysis and systematization of actual materials using complex analytical methods and ways (geological-geophysical, mineralogical-geochemical, thermobarogeochemical and isotope analysis, remote sensing, processing of the results of various types of analyzes through computer programs, building of geological sections and schemes, geological-genetic models and diagrams, etc.). At the same time, the published appropriate works of numerous researchers, partially the fund materials were used in the process of performing the work.

The main points of the defense:

1. Substantiation of the formation of ore-magmatic systems of the junction zones of the Murovdag and Aghdam anticlinoriums of the Lok-Karabakh island arc, the control of linear and annular structures with different directions and structures, their junction areas, contact areas of granitoid intrusives and volcano-tectonic structures.

2. Genetic or paragenetic relationship of ore-bearing magmatic complexes with porphyry copper, copper-polymetallic, copper-gold-pyrite and other types of mineralization.

3. Substantiation of long-term and multi-stage formation of endogenous ore deposits and occurrences of geological and physico-chemical conditions of mineralization, ore-metasomatic and geochemical zoning in ore-magmatic systems.

4. Predictive and search models of promising ore fields, search and predictive criteria for the revealing new ore deposits and occurrences.

Scientific innovations of the research: The main scientific innovations of the work are the building of genetic models of endogenous ore deposits belonging to the existing ore-magmatic system at the junction of the Murovdag and Aghdam anticlinors.

1) regional and local regularities of the formation and location of ore deposits and occurrences belonging to the existing ore-magmatic system have been revealed; 2) the geological and structural conditions of the ore-magmatic system were clarified by geological-geophysical and geochemical data based on the decoding results of cosmic and aerial photographs, and the structural and metallogenic role of annular structures and linear systems of fractures in the location of endogenous mineralization was determined; 3) using satellite data, promising areas for mineralization, which are characterized by hydrothermal-metasomatic alterations represented by alunitization, kaolinisation, sericitization, silicification, and propylitization were determined within the boundaries of the Murovdag ore region; 4) petrochemical and petrographic characteristics of magmatic rock complexes were analyzed, and it was determined whether mineralization was genetically or paragenetically related to magmatism spatially and temporally; 5) geochemical characteristics of wallrocks and ores and ore-metasomatic zoning were determined; 6) according to the material-mineralogical composition of the ores and the geochemical characteristics of the mineral associations, the stages of the mineralization process and the conditions of physico-chemical formation were clarified; 7) occurrence forms of copper, gold, silver and rare earth elements in ores of porphyry copper and copper-polymetallic deposits have been determined; 8) complex porphyry copper, copper-pyrite and copper-polymetallic deposits were studied, and their time-spatial relationship was determined; 9) vertical zoning was identified in the ore-magmatic system surrounding the porphyry copper mineralization, which confirms the adaptation of high amounts of Cu and Mo to lower horizons; 10) fluid inclusions have been studied,

allowing for building a formation model that includes the source of ore-bearing fluids in quartz veins, temperature conditions and depth of sedimentation of ore mineralization; 11) geological-genetic models of the formation of porphyry copper and copper-polymetallic deposits were developed; 12) the scientific bases of the predicrtion-search criteria and the main directions of future geological search-exploration works and metallogenic studies have been worked out.

Practical significance of the work. The use of the developed geological bases has been carried out for a long time by the author and with his participation in the geological-research and thematic works conducted in the Lesser Caucasus, especially in the Lok-Karabakh zone. It is justified that porphyry copper , copper-pyrite and copper-polymetallic, copper-gold-pyrite mineralizations are widespread in the region. The regularity determined about the composition and structure of ore bodies, geochemical aureoles, material composition of ores, gradation of the mineralization process, zoning and geochemical properties of metasomatites allow re-assessment of the industrial importance of deposits and occurrences within the studied ore-magmatic system, and conducting geological works first of all. Prospective areas for non-ferrous and noble metal mineralization have been observed in the Goshgarchay and Mehmana-Gizilbulagh ore fields, where volcano-tectonic structures are widely developed, by complex geological-geophysical and geochemical data based on the decoding results of space and aerial photographs, at the same time, with the use of satellite data, hydrothermal-metasomatic alteration and mineralization zones were found and promising areas for mineralization were determined. The scientific bases of the regional and local forecasting and assessment criteria of porphyry copper , copper-polymetallic and copper-gold-pyrite deposits have been developed. Analogous developments can be considered an important search factor in the observation of hidden mineralization for the prospective assessment of the lower horizons of poorly studied deposits and occurrences. Predicted maps of ore-bearing structures and minerals of Murovdag and Aghdam anticlinoriums have been drawn up.

The obtained scientific results are of theoretical and practical importance and can be used as search criteria for the effective operational assessment of the region's promising geological objects, which will allow to look at the issues of exploration of the region's ore-bearing from a new perspective and increase the country's mineral raw material base.

It is recommended to present the scientific results obtained in the dissertation work and the search and predicted criteria developed in the direction of the discovery of prospective areas and new types of ores to the Geological Exploration Expeditions of the Geological Exploration Agency of the Ministry of Ecology and Natural Resources and to companies engaged in the search and exploration of noble and non-ferrous metal deposits.

Approbation of the work and scientific publications. The results of the research were presented at republican and international scientific conferences and symposia. Republican Scientific Conferences (Baku, 1998; 2000; 2002; 2008; 2010; 2011; 2012; 2013; 2014, 2015, 2016, 2017, 2018, 2021, 2022, 2023), Republican Scientific Conference dedicated to the 90th anniversary of Prof. S.M. Suleymanov (Baku, 2001), The Republican conferences dedicated to the 100th anniversary of the Corresponding Member of ANAS H.Kh.Efendiyev (Baku, 2007), the 100th anniversary of Prof. A.H.Asgerov (Baku, 2007) and the 100th anniversary of academician M.M.Aliyev (Baku, 2008), 63rd Geological Congress of Turkey (Ankara, 2010), The International Scientific Conference, Problems of Geology of the Caucasus, Georgia (Tbilisi, 2010), Republican Scientific Conference dedicated to the 100th anniversary of Academician Sh.F. Mehdiyev (Baku, 2010), “Gold and deposits of the Mediterranean South Caucasus-Challenges and Opportunities” (Tbilisi, 2012), Conference on Recent Research Activities and New Results about Regional Geology, the Geodynamics and the Metallogeny of the Lesser Caucasus. A SCOPES meeting (Tbilisi, 2013), The material of 27th symposium on Geosciences of the Geological Survey of Iran (Iran, 2010, 2013), Republican scientific conference dedicated to the 70th anniversary of the Department of "Physical Geography" and the 40th anniversary of the Department of "Hydrometrology" (Baku, 2013), Scientific discourse: innovation in the modern world. 22nd International Scientific and Practical Conference (Moscow, 2014), X International Scientific-Practical Conference (Prague, 2014), 9th International scientific-practical conference. "Modern concept in scientific research" (Moscow, 2014), The Second International Applied Geological Congress. Department of Geology, Islamic Azad University-Mashhad Branch (Mashhad-Iran, 2015), 6th, 7th, 11th, 12th scientific-practical conference "Scientific-methodical bases of prediction, search and assessment of precious and non-ferrous metals, diamond deposits –

situation and perspective". METGKI (Moscow, 2016, 2017, 2022, 2023), The 36th National and the 3rd International Geosciences Congress, Iran, 2018, Magmatism of the Earth and related strategic metal deposits. Proceedings of 35th International Conference (Moscow, 2018), Scientific-practical conference "Actual problems of exploration geology" All-Russian Scientific Research Institute of Mineral Raw Materials named after N.M. Fyodorov (Moscow, 2023), Republican scientific conference dedicated to academician V. M. Babazade's 85th anniversary (Baku, 2023).

88 Scientific publications on dissertation (63 articles, 25 conference materials and thesis), 14 articles in International indexed journals (journals included to Web of Science base of Clarivate Analytics company), 7 articles in academic degree and scientific names purposed Earth science periodic journals in Russia, and 67 works were printed in different International and regional journals, congresses, conference and symposium materials.

Scope and structure of the work. Dissertation work consists of 395 pages including introduction, 6 chapters, conclusions and proposals, 414 references, 110 pictures, 40 tables: total volume – 524 665, including introduction – 17 718, chapter I – 64 412, chapter II – 68 654, chapter III – 24 952, chapter IV – 140

046, chapter V – 149 726, chapter VI – 46 815, conclusion and suggestions – 6 601 characters.

Gratitude. The author expresses his deep gratitude to the rectorate of Baku State University, Geology Faculty, researchers of Institute of Geology and Geophysics of the Ministry of Science and Education of the Republic of Azerbaijan, and the Geological Exploration Agency of the Ministry of Ecology and Natural Resources for their valuable scientific advice, conditions and help, who greatly supported the completion of the dissertation work.

GENERAL CHARACTERISTICS OF THE WORK

The first defended point. *Substantiation of the formation of ore-magmatic systems of the junction zones of the Murovdag and Aghdam anticlinoriums of the Lok-Karabakh island arc, the control of linear and annular structures with different directions and structures, their junction areas, contact areas of granitoid intrusives and volcano-tectonic structures.*

The formation of the secondary folding arc of the Lesser Caucasus, the compaction towards the Anatolian and Iranian plates, the longitudinal and transverse diagonal dislocations, the formation of systems, the transverse uplift zones of the Caucasus are related to the giant rupture fractures-transverse faults that control the occurrence of its orogenic effusive magmatism. The Lesser Caucasus is the main part of the Tethys orogenic belt, which stretches from the Black Sea to the Caspian Sea. This ribbon-like belt, extending to Asia, connects the Western and Central metallogenic belts of Tethys (Richards, 2015[1]). The Lesser Caucasus corresponds to the collision zones of the microcontinents marked by the subduction of the oceanic crust of the Lesser Caucasus limb of the Mesotethys, covering the edges of the Eurasian plate in the

[1] Richards, J.P.Tectonic, magmatic, and metallogenic evolution of the Tethyanorogen: From subduction to collision // Ore Geology Reviews, - 2015. v.70, - p. 323-345

north and the Iranian plate in the south (Geology of Azerbaijan: V. 4. Tectonics, 2005[2]).

According to the concept of the formation of the Lesser Caucasian mature island arc on the subduction zone lying to the north, from beginning the Middle Paleozoic and including the Middle Jurassic, researchers believe that since the Late Jurassic, the subduction front shifted to the north, and then sharply changed its direction to the south-southwest (Rustamov, 2005[3]; Geology of Azerbaijan: V. 4. Tectonics, 2005[2]; Khain, 2000[4]). The Lok-Karabakh zone is located parallel to the Kura depression, and is bounded by large thrust and upthrust-dislocations (Murovdag, Karabakh) that surround the ophiolite zone to the southwest and separate it from the Goycha-Hakara zone (Shikhalibeili, 1996[5]). This zone is intermittently characterized as an island arc, which is distinguished by calc-alkaline magmatism as a result of subduction of the Neotethys from the Jurassic to the Cretaceous. It is divided into different segments by transverse faults characterized by strong volcanism in Bajocian-Bathonian and Kimmeridgian. The model of geodynamic development of the region, which was proposed by a number of researchers (Geology of Azerbaijan: V. 4. Tectonics, 2005[2]; Khain, 1984[4]), allows to explain sufficiently the petrological seriality and petrochemical polarity in the development of magmatism, the observed metallogenic zoning – Late Kimmeridgian and Alpine tectono-magmatic cycles and the formation of metallogenic epochs in the Lesser Caucasus. Zonally developed copper-pyrite and polymetallic, porphyry copper, skarn-magnetite, gold-polymetallic, copper-molybdenum-porphyry, antimony-

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[2] Геология Азербайджана: [в 10 томах] / Под ред. академика А.А.Ализаде. – Баку: Нафта-Пресс, –т.4, Тектоника – 2005. – 505 с.

[3] Рустамов, М. И. Южнокаспийский бассейн-геодинамические события и процессы / М. Рустамов. –Баку: Nafta-Press, 2005. –345 с.

[4] Хаин, В.Е. минерагенезе // – Москва: Геология рудных месторождений, – 2000.Основные этапы тектонического развития Земли и их отражение в т.42, №5, –с.403-408

[5] Шихалибейли, Э. Некоторые проблемные вопросы геологического строения итектоники Азербайджана / Э. Шихалибейли. –Баку: Элм, –1996. –215 с.

mercury-arsenic and other ore deposits and occurrences were formed within the region (Geology of Azerbaijan, vol. 6, Useful minerals, 2003[6]).

The principles of segregation and study of the ore-magmatic system of the region are currently considered the superior and more informed direction in the theory of endogenous ore formation with optimal criteria for the search and prediction of endogenous ore deposits (Azadaliyev, 1998[7]; Baba-zadeh, et al., 2012[8]).

The main goal for the purpose of metallogenic research and distinguishing the ore-magmatic system is to study the regularity of the formation and location of mineral deposits and the evolution of geological processes and their spatial and temporal relationship, and the main element is the processes of magmatism and mineralization (Babazadeh, etc., 2012[8]).

The analysis of materials on non-ferrous and noble metal systems in the Lok-Karabakh mature island arc shows that the ore-magmatic system develops on a single principle with sour rocks of Late Jurassic-Early Cretaceous magmatism and has an asymmetric zonal structure. They are highly metallic, promising for noble and non-ferrous metals, and are located in certain areas of island arc volcanism, forming a general zonation (Babazadeh, etc., 2012[8]).

According to J. A. Azadaliyev (1998[7]), the ore-magmatic system includes the sum of all endogenous processes that lead to the formation of deposits and ore occurrences of one or another formational affiliation under different depth conditions.

The distinguishing principles of the ore-magmatic system are mainly based on the existence of a regular interaction of ore-bearing magmatic bodies, ore and hydrothermally altered host rocks. In agreement with the current views, we also prefer the gen-

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[6] Геология Азербайджана: [в 10 томах]. / Под ред. академика А.А.Ализаде. - Баку: Нафта-Пресс, – т.4, Полезные ископаемые– 2003. – 574 с.

[7] Азадалиев, Дж.А. К проблеме рудно-магматических систем (на примере МалогоКавказа) // Баку: Доклады Академии Наук Азербайджана, т.LIV, – 1998. № 5-6, –с.114-121

[8] Баба-заде, В.М. Благороднометальные рудно-магматические системы / В.М. Баба-заде, Ш.Ф. Абдуллаева, –Баку: Бакинский Университет, –2012, –275с.

erally accepted definition of the ore-magmatic system by L.V. Tauson et al. (1987[9]) in the study of the ore-magmatic system. According to L.V.Tauson et al. (1987[9]), “the ore-magmatic system is the natural data of the magmatic, metasomatic and ore formations, as well as the formation of concentration of elements geochemical fields at the ore level, which are determined by the activity of the genetic interaction of geological processes”.

The ore-magmatic systems represented by the porphyry copper, copper-polymetallic, copper-pyrite and gold-bearing deposits of Murovdag and Mehmana ore region were taken by us as reference-type research objects. These deposits belong to different genetic and ore formation types, which are close to each other according to their mineral composition in many cases, but differ according to the petrochemical properties of magmatic rocks (Babazadeh, et al., 2012[8]).

The Murovdag anticline subzone extends from west to east along the watershed of the Shahdag and Murovdag ranges, covering the Shahdag, Gamish and Murovdag highlands. Most researchers consider this structure as an integral part of the Lok-Karabakh fold zone. According to A.Sh.Shikhalibeyli (Shikhalibeyli, 1996[5]), the second-order Murovdag anticlinorium is located after the Gamish-Toraghaychay thrust and is connected to the first-order Goyche-Hakara synclinorium, and this thrust reflects the deep fault zone and is separated from the eastern Shahdag range by the depth-specific Karabakh fault. The geological structure of anticlinorium is composed of Middle Jurassic volcanogenic formations (Khain, 1984[5]; Geology of Azerbaijan: V. 4. Tectonics, 2005[2]).

Large transversal depth faults within the anticlinorium are represented by the Goygol-Khoshbulag faults in the west, and the Murovdag-Zod faults in the eastern flank. Faults are characterized by the older NW (280-300°), near meridional (330-10°) and meridional, and relatively young near latitudinal (80-100°) and latitudinal directions (Geology of Azerbaijan: V.4. Tectonics, 2005[2]).

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[9] Таусон, Л.В. Геохимические поля рудно-магматических систем / Л.В.Таусон, Г.М. Гундобин, Л.Д. Зорина, –Новосибирск: Наука, –1987, –202 с.

The Aghdam anticlinorium covers the area between the Terterchay and Gargarchay rivers and is located as a horst between the Khojavand synclinorium in the southwest and the Kura megasynclinorium in the northeast. Its geological structure includes the Middle and Late Jurassic volcanogenic, volcanogenic-sedimentary and sedimentary rock complexes. This structure connects with the Murovdag anticlinorium in the northwest direction. This gives a number of researchers the reason to mention the Aghdam anticlinorium as a free structure, and they came to the conclusion that the Murovdag and Aghdam anticlinoriums and the Aterk, Khojavend synclinoriums as a whole form a single structural system in the NW direction (Geology and Minerals of Nagorno Karabakh (Azerbaijan), 1994[10]).

In order to determine the structural and metallogenic properties of ore-magmatic systems within Murovdag and Aghdam anticlinoriums, the following works were carried out using complex geological-geophysical, geomorphological and geochemical methods based on the decoding results of space and aerial photos: 1) structural-geological decoding of space photos of different generalizing levels in order to found lineaments and annular structures; 2) decoding of aerial and space photos at a scale of 1:200,000 for the entire area; 3) decoding of different more interesting areas of the region on different scales from the structural and metallogenic point of view; 4) complex analysis and comparison of the decoding results of space and aerial photos with the preliminary data of previous geological-planning, prediction, metallogenic and other large-scale geological maps and geological-geophysical studies (Katz, 1976[11]). Numerous annular structures (Gizilbulagh, Drombon, Imarat-Garvand, etc.) of different sizes, morphologies and genesis, which were separated as a result of decoding work, vary in small (1.5-5.5 km), medium (15-20 km) and large (up to 50-60

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[10] Геология и полезные ископаемые Нагорного Карабаха (Азербайджан) / Под ред. Э.Ш.Шихалибейли, Р.Н. Абдуллаев, Т.А.Гасанов [и др.] / –Баку: Элм, –1994. –284с.

[11] Кац, Я.Г., РябухинА.Г., ТрофимовД.М. Космические методы в геологии / Я.Г. Кац,– Москва: Московского университета, –1976. – 247с.

km) sizes according to their diameters. Most of these structures were discovered for the first time and determined to correspond to volcanogenic, volcanogenic-sedimentary and intrusive complexes.

Recently, spectrometry of satellite data such as Landsat and ASTER has been used to found ore deposits within ore regions and areas, and in the spatial determination of mineral indicators in geological situations, as well as in the founding of promising areas for mineralization, which are characterized by hydrothermal-metasomatic alterations (Abrams et al., 1985[12]; Tommaso et al., 2007[13]; Mansurov et al., 2021[14]).

Murovdag ore region is characterized by extensive development of porphyry copper, copper-pyrite and copper-polymetallic ores and their corresponding alterations. The possibility of founding hydrothermal-metasomatic alterations based on remote sensing data creates great opportunities for effective geological research in this area (Abrams et al., 1985[12]). Hydrothermal alterations are considered an important source of information in mineral exploration and prediction. From this point of view, found and research of alteration zones in the territory of the ore region was carried out using remote sensing data. Alteration components were observed based on their diagnostic spectral bands within the principal components (Abrams, et al., 1985[12]; Tommaso, et al., 2007[13]). Alteration zones determined by remote sensing were analyzed by geological prospecting and field inspections. The results show that K-spars are represented by kaolinisation, sericitization, silicification,

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[12] Abrams, M.J., Brown, D., Silver Bell., Arizona, porphyry copper test site: the Joint NASA-Geosat test case study, Section 4, Tulsa, OK // American Association of Petrolium Geologists, –1985. –73 p.

[13] Tommaso, I.D. Nora Rubinstein, N., Hydrotermal alteration mapping using ASTER, data in the Infiemillo porfhyry deposit, Argentina // Ore Geology Reviews, – 2007. v. 55, – pp. 70-79.

[14] M.Mansurov, N.Imamverdiyev, V.Karimov, E. Ganbarova, T.Damirov, S. Mursalov, N. Pashayev The discovery of structural elements and zones of hydrothermal alterations by using ASTER satellite data in the margins of Gadabay and Murovdag ore districts (Lesser Caucasus, Azerbaijan) // Journal Geology, Geografy and Geoecology. Dnepropetrovcsk, Ukrain. 2021, 30 (3), p.512-527.ISNN 2617- 2909.Doi:10.15421/112147

and prophylitization based on OH alterations. Such alterations are considered typical for porphyry copper, gold-porphyry copper deposits. Fe^{2+}(Fe^{3+}) alterations are mainly seen as the result of pyritization. This is considered as an indicator of polymetallic deposits in the area. The distribution of hydrothermally altered clay minerals, especially alunite, illite, and kaolinite in the study area indicates strong hydrothermal activity here. The presence of alteration types such as K- spathization, prophylitization and silicification confirms indirectly that hydrothermal activity in the study area occurs at medium and low temperatures (Ninomiya, 2003[15]).

The second defended point. *Genetic or paragenetic relationship of ore-bearing magmatic complexes with porphyry copper, copper-polymetallic, copper-gold-pyrite and other types of mineralization.*

Modern ideas about the geological structure, history of tectonic development, metallogeny and magmatism of the Lesser Caucasus are reflected in the works of V.M.Babazadeh, J.A.Azadaliyev, M.I.Rustamov, A.Sh. Shikhalibeyli, A.J. Ismayilzadeh, Sh.A.Azizbeyov, R.N.Abdullayev, T.N.Kangarli, V.Y. Khain, S.A.Bektashi, V.I.Aliyev, F.A.Akhundov, M.N.Mammadov, M.A.Gashgai, H.Kh.Efendiyev, H.V.Mustafayev, S.M.Suleymanov, T.H.Hajiyev, V.G.Ramazanov, D.A.Huseynov, B.H.Galanderov, N.A.Imamverdiyev, E.S.Suleymanov, H. I.Karimov, A.F.Karimov, A.A.Bayramov, H.M.Hasanov, M.A.Mustafayev, Y.I.Potopova, D.M.Ahmadov, Z.A.Valiyev, Sh.F.Abdullayeva, G.S.Huseynov, Z.I.Mammadov, A.M.Ismayilova, etc.

Intrusives of the Murovdag group were divided into Goshgardag and Gizilarkhaj groups by R.N.Abdullayev (1988[16]) according to their geological position and spatial location. Intrusives

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[15] Ninomiya, Y. A stabilized vegetation index and several mineralogic indices defined for ASTER VNIR and SWIR data – Proc. // IEEE International Geoscience and Remote Sensing Symposium, v.3, Toulouse, Franse, – 2003. 21-25 july, – p. 1552-1554

[16] Мезозойские магматические формации Малого Кавказа и связанное с ними эндогенное оруденения / Р.Н.Абдуллаев, Г.В. Мустафаев, М.А.Мустафаев (и др.), Баку: Издательство Элм, – 1988. – 160 с.

of the Goshgardag group are located on the eastern and western slopes of Goshgardag Mountain, at the junction of the Balaja and Boyuk Qashgachay rivers. Outcrops of the Ojagdag intrusive are represented by transversely layered bodies, as well as small stock-like bodies, and they are represented petrographically by quartz diorite, gabbro-diorite, a small amount of diorite, gabbro and banatites (Geology of Azerbaijan: V. 3, Magmatism[17]).

Intrusive massifs were opened at a shallow depth by erosion processes, and only the crust of the massif participates on the upper surface. The contact surface of the intrusive is rough and dips at an angle of 55-65° towards the host rocks. This factor shows that intrusives can be attributed to solid bodies expanding at depth. T.Ab.Hasanov (1996[18]) discovered stock-shaped and dyke-shaped small outcrops of ultramafic rocks (hyperbasites) among the Early Bajocian volcanites at the junction of Boyuk and Balaja Gashgachay rivers.

According to new petro-geochemical data, it was determined by V.M.Babazadeh et al. (2008[19]) that ultramafic volcanic rocks - picrites, picrobasalts and picrodolerites occur in this region, and their age corresponds to the Kimmeridgian Age of volcanism. Also, picrobazalts are also found in the form of thin subvolcanic bodies among Kimmeridgian volcanics within the Elbeydash syncline (Abdullayev, and others 1988[15]).

Here, Kimmeridgian vulcanites and picrobasalts are subalkaline and are associated with trachyandesite and trachydasite. Ac-

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[17] Геология Азербайджана: [в 10 томах]. / Под ред. академика А.А.Ализаде. - Баку: Нафта-Пресс, – т. 3, Магматизм – 2001. – 434 с.

[18] Гасанов, Т. Аб. Геодинамика офиолитов в структуре Малого Кавказа и Ирана /Баку: Элм, –1996. –449 с.

[19] Баба-заде В.М., В.М. Баба-заде, М.Н. Мамедов, В.Г. Рамазанов (и др.Ğ. Петролого-геохимические особенности формирования пикритов и пикробазальтов Мровдагского антиклинория (Малый Кавказ) // Вестник Бакинского Университета. Серия естественных наук,Баку –2008. № 1, – с.105-116

cording to M.A. Mustafayev (2000[20]), the amount of alkali in these rocks increases to 7.40-9.0%. According to their composition (MgO – 15-20%; K_2O – 0.9-2.5%; Ni – 210 g/t; Cr – 36-400 g/t), these rocks correspond to picrite and picrobasalt.

As can be seen from the petrochemical analysis, the Late Jurassic (Kimmeridgian) - Early Cretaceous (Neocom) multiphase intrusives are composed of gabbroid and quartz diorite phases. The latter are associated with monzodiorites, monoquartz diorites and syenites. Each of these phases is distinguished by its own mineralization.

The intrusives of Murovdag complex are located between the calc-alkaline trend and the alkaline trend in the AFM diagram. The calc-alkaline trend corresponds to the direction of alkaline area, and the tholeitic trend corresponds to the direction of ferruginous area. As it can be seen, the evolution of magma took place in a fairly wide variation of alkalinity and iron content. Picrite and picrobasalts are low in titanium (TiO_2 - 0.40-0.57%) and potassium (K_2O-0.06-0.42%) according to their petrochemical properties. Besides, high amounts of iron oxide (FeO-10.15-16.10%) and low amounts of Ca, Mn and Al are observed in all analyses (Babazadeh, et al. 2008[18]; Geology of Azerbaijan: V. 3, Magmatism[17]).

Bajocian basalt-rhyolite, Bathonian andesite-dacite-rhyolite, and Late Jurassic-Early Cretaceous basalt-andesite-dacite formation are developed within Murovdag anticlinorium. Bajocian volcanics of both complexes belong to sodium ($Na_2O/K_2O>4$) and potassium-sodium ($Na_2O/K_2O=0.4-4.0$) series (Abdullayev and others, 1988[16]).

The determining peculiarities of rare earth elements in the metasomatites and host rocks of the Goshgarchay ore-magmatic system were reviewed and it was determined that all rocks, including metasomatic rocks are characterized by a slight advantage of

[20] Мустафаев, М.А. Мезозойский вулканизм Азербайджана и палеогеодинамические обстановки его формирования // –Баку: ИзвестияНациональный Академии Наук Азербайджана, Науки о Земле, –2000, № 1, –с. 27-33

light lanthanoids over heavy lanthanoids. The ratio of La/Yb is 1.4-4.6. A significant advantage of light lanthanides over heavy ones is observed only in diorites, La/Yb=13.4. The ratio of Ce/Ce* is 0.81-1.03 in metasomatites. Absence of Ce anomaly in metasomatites may show the dominance of magmatogenic fluids in the composition of fluids that formed metasomatites and ore mineralization (Vinokurov, 1996[21]).The determining trends of rare earth elements in metasomatites reflect the determining characteristics of these elements in primary rocks (gabbroids, diorites and andesites) subjected to metasomatic alterations. However, the maximum value of the sum of rare earth elements is observed for diorites (91 g/t), and the minimum for gabbro (6.5 g/t). Diorites enriched in light lanthanides occur with increasing ratio of Ce/Yb. In contrast to other rocks, the ratio for these rocks is 25.7, which shows the magmatogenic origin of the fluids (Imamverdiyev, 2020[22]; Balashov, 1976[23]).

Analysis of the data shows that the host rocks and metasomatites have close determination parameters of rare earth elements and both types of rocks have uniform fluid nature. By characterizing the determination of rare earth elements in the igneous and metasomatic rocks of the Goshgarchay ore-magmatic system, the following conclusions can be come: 1) metasomatites and host rocks are characterized by the predominance of light rare earth elements over heavy elements, rare earth elements have a uniform genesis; 2) rare earth elements show different mobility during the formation of ore metasomatites: light rare earth elements (La to Sm) show minimal mobility, and heavy rare earth elements show

[21] Винокуров, С.Ф. Европиевые аномалии в рудных месторождениях и их генетическое значение / Москва; Доклады Российский Академии Наук, 1996. т.146, №6, – с.792-795

[22] Имамвердиев, Н.А.,Баба-заде,В.М., Мансуров М.И., Абдуллаева Ш.Ф. Редкоземельные элементы в магматических и метасоматических породах Муровдагского рудного района (Малый Кавказ)// Геохимия, –Москва; –2020, т.65, № 2, с.178-184

[23] Балашов, Ю. Геохимия редкоземельных элементов / Ю. Балашов –Москва; Наука, –1976. –267с.

maximum mobility; 3) the fact that metasomatites and host rocks have similar determination parameters indicates that analogous igneous rocks are the substrate for metasomatites.

The geological characteristics of the Mehmana intrusive complex are reflected in the works by R.N.Abdullayev, Sh.A.Azizbeyov, A.J.Ismayilzadeh, M.I.Rustamov, M.A.Gashgai, A.D.Karimov, H.V.Mustafayev, A.Sh.Shikhalibeyli and others. According to A.Sh.Shikhalibeyli (Shikhalibeyli, 1966[6]) and others, this intrusive complex is located at the junction of the Aghdam anticlinorium and the Delidag-Mehmana transverse uplift in the southwestern part of the Lok-Karabagh zone. The age of the intrusive was accepted as Late Jurassic-Early Cretaceous (Neocom) by K-Ar method (Abdullayev, 1979[24]).

Intrusive rocks belong to the normal petrochemical series according to alkalinity, and to the potassium-sodium series according to the ratio of Na_2O/K_2O (3.61). As a whole, intrusive complexes are characterized by high siliceousness (Abdullayev and others, 1988[15]). Two groups are distinguished according to the amount of silicium among the intrusive rocks: medium (SiO_2 =60.91%) (or medium sour) and sour (SiO_2=64.65%). According to the amount of SiO_2, two types are distinguished among the medium-acidic group: diorites (Si56.40% to 56.92%) and quartz diorites (Si=59% to 63.99%) (Kerimov, 1965[25]).

Volcanogenic complexes are represented by Late Jurassic-Early Cretaceous basalt-andesite-dacite formation and are considered the main wallrocks of endogenous ore deposits belonging to some formations (Abdullayev et al., 1988[16]; Geology of Azerbaijan: V. 3, Magmatism[17]).

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[24] Абдуллаев, Р.Н. Возрастное расчленение магматических образований северо-восточной части Малого Кавказа по данным К – Ar метода / Р.Н. Абдуллаев, А.Р. Исмет, О.Д. Багирбекова [и др.] – Баку: Элм, –1979. –146 с.

[25] Керимов, А. Петрология и рудоносность Мехманинского гранитоидного интрузива / А. Керимов, –Баку: Академии Наук Азербайджанская ССР, –1965. –165 с.

The third defended point. *Substantiation of long-term and multi-stage formation of endogenous ore deposits and occurrences of geological and physico-chemical conditions of mineralization, ore-metasomatic and geochemical zoning in ore-magmatic systems.*

Murovdag ore region is characterized by the prospect of porphyry copper, copper-pyrite, copper-polymetallic and other types of ore deposits and occurrences. Two ore-magmatic systems are separated within the ore region: Goshgarchay and Gizilarkhaj. The first of these includes the Goshgarchay and Goshgardagh porphyry copper, as well as the Chanakhji and Zivlan copper-pyrite deposits and occurrences. The second includes the Gizilarx-haj, Kecheldag, Jamillibulag, Erik-Manuc and Elbeydash porphyry copper and copper-polymetallic deposits and occurrences. We tried mainly to investigate the geological-genetic characteristics of the first ore-magmatic system.

Porphyry copper mineralization covering Goshgarchay, Goshgardag, Gizilarkhaj and other deposits and occurrences in the Murovdag ore region is spatially and genetically associated with the granitoid intrusive of the same name. The intrusives that make up the ore-magmatic system, the Goshgarchay complex that forms the effusive-pyroclastic complex and creates a contact-thermal relationship with them, consists of granitoid intrusives (Goshgardag, Ojagdag, Balaja Goshgardag) and their dyke systems.

Fracture structures with different directions that create the block structure of the ore-magmatic system play an important role in the spatial determination of porphyry copper and copper-polymetallic mineralization in the ore region (Babazade and others, 1990[26]).

Goshgarchay porphyry copper deposit. The deposit is considered the most promising deposit of the ore-magmatic system of the same name and is located on the southwestern flank of the

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[26] Баба-заде, В.М., Махмудов, А.И., РамазановВ.Г. Медно- и молибден порфировые месторождения / Баку: Азернешр, –1990, –376 с.

Murovdag anticlinorium, adapted to the endo- and exocontact zone of the gabbro-diorite-garanodiorite formation intrusive belt (Babazade and others, 1990[26]).

The closest and Caucasus-oriented faults in the region are considered to be direct ore-bearing structures, and the northwest-oriented faults that cross the Goshgarchay fault from the dependent side are considered to be ore-locating structures. This is explained by the following factors: 1) localization of ore zones at the moment of dependence of fault; 2) ore zone and faults falling in the same direction at a steeper angle; 3) localization of ore zones in small fracture systems and locally significant faults; 4) adaptation of intensively hydrothermally altered rocks and impregnated sulfide mineralization to major faults of subvolcanic masses and dykes (Babazadeh et al. 1990[26]; Znamenisky, 2008[27]).

Ore-metasomatic zonation. The zonation of minerals and chemical elements in the ore masses of hydrothermal deposits is directly related to the zonation of wallrock metasomatites. From this point of view, porphyry copper deposits, which clearly show the horizontal and vertical zonation of various formations of ore-forming elements and metasomatites, are considered typical (Omelianenko, 1978[28]).

During the formation of the Goshgarchay massif, the segregation of metal-bearing fluids varied, which led to the formation of a wide propylitization zone related to the initial phase, and then to the formation of potassic, quartz-sericite, and quartz metasomatites and argillization related to the acidic late phase. Most of the formation of industrially important porphyry copper mineralization occurred as a continuation of the occurrence of the early genera-

[27] Знамениский, С.Е. Структурные условия формирования коллизионных месторождений восточного склона Южного Урала / автореферат диссертации доктора геолого-минералогических наук / –Москва; –2008. –47с.

[28] Омельяненко, Б. Околорудные гидротермальные изменения пород. /Б.Омельяненко,–Москва: Недра, – 1978. – 215 с.

tion of porphyries (Azadaliyev, 2017[29]; Ramazanov, 1993[30]).The late phase of the porphyry is accompanied by intense silicification, which allows to note the possibility of the formation of a “quartz core” in the central part of the deposit (Popov, 1977[31]).

Three metasomatic zones are separated in the shape of an ellipse around the quartz-diorite porphyry intrusive stock in the structure of the metasomatic column within the Goshgarchay ore-metasomatic system (Baba-zadeh et al, 1990[26]): 1) *the inner zone* was represented by intensely secondary quartzites covering the endocontact and apical part of the porphyry intrusive. According to the mineral composition, this zone corresponds to the quartz-sericite facies of the secondary quartzites, and its mineralization is usually weak. A gradual increase in the amount of sulfides is observed with depth, and the amount of Cu increases from 0.01% to 0.15%; 2) *the middle zone* separates as a quartz-sericite-chlorite facies of secondary quartzites. The mineral composition of metasomatites is represented by quartz, chlorite, sericite, epidote, calcite and pyrite. The development of mineralization is particularly characteristic of the quartz-sericite-chlorite facies; 3) *the outer zone* of the metasomatic column was represented by the propylite facies of secondary quartzites. Here, propylitization has a regional distribution. New formations, which are represented by chlorite, epidote, albite, sericite, as well as actinolite and pyrite, have undergone weak alteration in the zone.

The following main features are observed in the zoning of metasomatites in the porphyry copper deposits of the Goshgarchay ore-magmatic system: 1) positional connection with granitoid porphyry intrusive; 2) replacement of the biotite-kalifeldspath-

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[29] Азадалиев, Дж.А., Керимов, Ф.А. Метасоматизм и рудогенез эндогенных месторождений Нахчыванской АР.Баку: –2017. –605 с.

[30] Рамазанов, В.Г. Медно-порфировая формация Азербайджана: /автореферат диссертации доктора геолого-минералогических наук / –Тбилиси, 1993. –45 с.

[31] Попов, В. Геология и генезис медно- и молибден-порфировых месторождений / В. Попов, – Москва: Наука, –1977, –203 с.

quartz-sericite-propyllite metasomatite zone; 3) the vertical zoning order of elements is represented by Mo → Cu → Co → Ni → Cr → Ag → Pb → Zn; 4) impregnated -veinlet type of mineralization (Baba-zadeh et al., 1990[26]; Marushchenko et al., 2015[32]).

A complex geological model of the porphyry system began to be formed as a result of development of numerous geological, petrological and metasomatic indicators. The most perfect of them belongs to R.N. Sillitoe (Sillitoe, 2010[33]). Besides other types of deposits, the position of porphyry copper deposits is shown in this model. According to this model, it can be stated that the main factors of metasomatic alterations in the Goshgarchay ore-magmatic system are small porphyry intrusives of the surrounding ledge, stock and dyke type, the composition of primary rocks, breccia and ore masses, ore-metasomatic zoning, mineralogical composition of ore-bearing metasomatites, etc. (Bean et al., 1984[34]).

According to the ore-metasomatic characteristics of the porphyry copper deposits of the Goshgarchay ore-magmatic system, the following can be stated: 1) intrusive complexes associated with porphyry copper mineralization belong to the Late Jurassic-Early Cretaceous gabbro-diorite-granodiorite formation according to their geological and petrological characteristics; 2) the segregation of metal-bearing fluids was repeated many times and first led to the formation of a large propylite zone associated with the early phase and then, the formation of potassic, quartz-sericite and quartz metasomatites and argillization associated with the acidic late phase; 3) Metasomatic formations of porphyry copper deposits were represented by the successive occurrence of kalifeldspath,

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[32] Марущенко Л.И., Бакшеев И.А, Нагорная В. (и др.). Кварц-серицитовые метасоматиты и аргиллизиты Au-Mo-Cu месторождения Песчанка (Чукотка) // Геология рудных месторождений, – Москва: – 2015. т. 57, № 3, – с. 239-252

[33] Sillitoe, R.H. Porphyry Copper System // Society of Economic Geology, – 2010. v.105, p. 3-41

[34] Бин Р.Э., Титли С.Р. Медно-порфировые месторождения / В кн.: Генезис рудных месторождений Москва; Мир, – 1984, – с. 245-321

greisen, propylite, secondary quartzite and argillaceous formation; 4) the main volume of industrially important porphyry copper mineralization is controlled by porphyry stocks and breccia masses, and sometimes they carry the ground mass of the ore material (Mongush, 2013[35]).

The presence of numerous chemical elements (Ag, Al, As, Ba, Bi, Ca, Cd, Ce, Cr, Cu, F, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Sr, Ti, V) in the wallrocks of the Goshgarchay ore-magmatic system was determined through spectral analysis. Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V and Sr are considered more stable elements among this group of elements. The ore elements in the host rocks are divided into three free groups: according to the first group: 1. Ag-Cu; 2. Bi-Cd-Pb; 3.Cr-Mo; according to the second group: 1. Al-Ca-Mn; 2. Mg-V-Sc-Ti; 3. Na-Sr-Ce-Ni-Fe-Zn-As-P; according to the third group: Ba-K-S (Mansurov, 2021[36]).

Among ore elements, stable elements (Cu, Mo, Pb, Zn, Ag, Ni, Co, Mn, Ti, Cr, V, Sr) typical for hydrothermal deposits can be considered indicator elements of a porphyry copper deposit within the ore-magmatic system we are considering.

According to the results of cluster analysis, it can be stated that the elements (Mn, Ti, Cr, V, Sr) that are less typical for hydrothermal solutions keep their independence in all host rocks, and the presence of their grouping is most likely related to the processes of their transportation from the silicate rocks with the surrounding basic-medium composition. Elements such as Cu, Mo, Ag, Pb, and

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[35] Монгуш, А-Д.О., Лебедев, В.И. Ак-Сугское медно-молибден-порфировое месторождение: вещественный состав пород и руд // – Иркутск: Известия Сибирского отделения Секции наук о Земле Российской академии естественных наук. Геология, поиски и разведка рудных месторождений, – 2013. № 1 (42), – с. 22–29

[36] Мансуров М.И. Особенности размещения и условия формирования Кошкарчайского медно-порфирового месторождения (Малый Кавказ, Азербайджан) // Вісник Киіевського національного університета іменіТараса Шевченка, Геология, 2021, № 2 (93).с. 41-52, DOI: http: // org/ 10.17721/1728-1713.93.05

Zn, which form a free group, are generated from a magmatic source during the differentiation process of crystallization and are related to the degree to which the rocks are exposed to hydrothermal activity, which is considered the source of these elements (Nikolaev and others 2016[37]).

Cu and main ore components (Mo, Ag, As, Bi, Gd, Co, Cr, Se, Ge, Li, Nb, etc.) are equally dependent on each other in the ores of the Goshgarchay deposit, and the amount of Cu in the ores has a positive correlation with Ag, As, Bi, Cd, Ce, Ge, Sr, Mo, Sb, Se, Th, and Ti, and a negative correlation with Co, Cr, Cs, La, Li, Pb, Rb, Ni, Nb, and Zn.

During the analysis of the graphs built on the amount of the main ore components of the considered ore-magmatic system, a positive straight-line correlation of Cu with Ag, As, Bi, Cd, Ge, Co, Mo, Cr, Ni, Pb and Rb is observed, and you can see that they are equally dependent on each other.

In order to determine the characteristics of the distribution of chemical elements in the Goshgarchay field, point dependence graphs between the elements were built. The vertical axis of the graph shows the dependent variables, and the horizontal axis shows the independent variables. As you can see in the graphs, point clouds for individual elements are drawn in a completely precise direction. This is explained by the fact that the ore masses in the upper part of the deposit have undergone a sharp enrichment due to the oxidation process. Due to this, an increase in the amount of Cu is observed. Newly formed sulfides (chalcocine, covelline, bornite, malachite) occurred in the oxidation zone. This shows that our sample includes products of hypogene and hypergene mineral formation stages. As can be seen, most of the point clouds in the relationship graph of Cu and Mo with other components lie along

[37] Николаев, Ю.Н. Николаев Ю.Н., Бакшеев И.А., Прокофьев В.Ю. и др. Au-Ag минерализация порфирово-эпитермальных систем Баймской зоны (Западная Чукотка, Россия) // Геология рудных месторождений, – Москва: – 2016. т. 58, № 4, – с. 319-345

the straight line, and some lie outside the line. This is normal in the determination of elements, where the low and high values of the elements do not deviate much from the straight line. This confirms that all the abovementioned elements are the product of one geochemical process (Grabezhev, 1985[38]).

According to the analysis of the data, it can be concluded that three different mineral associations are involved in the mineralization process in the deposit: 1) primary sulphide minerals; 2) oxidized ores; 3) primary sulphide minerals significantly enriched by products of ore-bearing hydrothermal solutions.

The method of factor analysis was used when solving the problems of determining the main ore components, its genetic and geochemical characteristics. According to the results of chemical analysis, the main ore elements are combined into two groups: 1 - Cu, Mo, Pb, Zn, Sb, As; 2 - Ni, Co, Ti, V, Cr, Bi. As a result of the treatment, two factors reflecting the correlation between the six ore components of the first group were obtained.

All factors are considered to be ore-bearing, or rather, the elements, which are characterized by the maximum charge in these factors, took part in the process of ore formation. The calculated factor loading, specific value and factor weight show that the properties of Cu, Mo, Pb, Zn, Sb, As elements are determined by the F_1 factor (Table 1; 2). The analysis of the main components of the F_1 factor shows that there is a significant positive correlation between the factor loading and Cu (0.819067), Mo (0.694623), Sb (0.927197) and As (0.87989), a significant negative correlation with Zn (-0.24141), and a weaker but positive correlation with Pb (0.097005). Such a selection of the main components and their behavioral characteristics allow to conclude that the F_1 factor shows

[38] Грабежев, А.И., Чащухина, В.А. О корреляции между элементами медно-порфировых месторождений // Геохимия, – Москва; – 1985. № 12, – с.1792-1794

the ore deposition process with the introduction of Cu, Mo, Sb and As elements (Mansurov, 2022[39]).

The analysis of F_2 factor loading shows that it has a significant positive relationship with the elements Cu (0.24515) and Mo (0.253405), a negative relationship with the elements Pb (-0.85986), Zn (-0.71234) and Sb (-0.20243), and a weaker but positive relationship with the element As (0.018338). Such a state of the F_2 factor suggests that the migration and concentration of Cu and Mo elements in the main mineralization process took place under different conditions.

The importance of factor F_1, which corresponds to Cu (Mo) association, is statistically related to the preservation of chalcopyrite and molybdenite in Cu-Mo porphyry mineralization (chalcopyrite-molybdenite). The positive correlation between the F_2 factor and the amount of Pb, Zn, Sb and As elements confirms spatially and indirectly the occurrence of porphyry copper mineralization in the porphyry and subepithermal stage of the ore deposition process (Mansurov, 2018[40]).

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[39] Mansurov, M.I., Geochemical features of porphyry copper mineralization in the Goshgarchayore magmatig system (Murovdag ore region, Azerbaijan part of the Lesser Caucasus), Вісник Киіевського національного університета іменіТараса Шевченка. Геология, – 2022. 4(99), – p.51-59

[40] Mansurov M.İ. Qoşqarçay filiz-maqmatik sistemində başlıca filiz komponentlərinin təyin olunma xüsusıyyətləri (Murovdağ filiz rayonu) // Bakı Universitetinin Xəbərləri, Təbiət elmləri seriyası, 2018, №4, s. 52-60

Table 1

Factor loading, specific value and factor weight
on the main components

Elements	**F_1**	**F_2**
Cu	**0,819067**	**0,24515**
Mo	**0,694623**	**0,253405**
Pb	0,097005	-0,85986
Zn	-0,24141	-0,71234
Sb	**0,927197**	-0,20243
As	**0,87989**	0,018338
Specific value	2,854961	1,41241
Factor weight	0,475827	0,235402

Note: in bold - the significant value of the factor loading is given

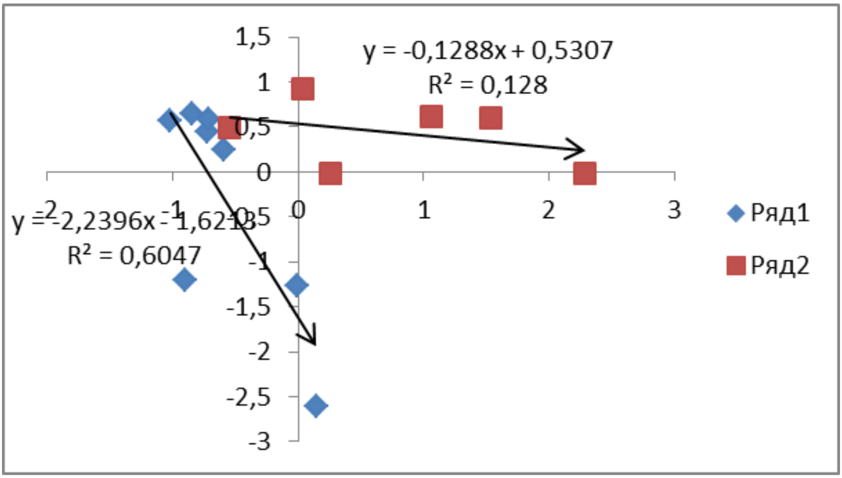

Figure 1. Dependence diagram of factors F_1 and F_2 on the results of factor analysis (on Cu, Mo, Pb, Zn, Sb and As elements)

Table 2

Factor loading, specific value and factor weight

Elements	**F₁**	**F₂**	**F₃**
Ni	**0,94983**	**0,123226**	0,088395
Co	**0,959018**	0,042407	0,129709
Ti	-0,30861	-0,84415	0,003185
V	0,057914	0,007864	0,994674
Cr	**0,903098**	0,29171	-0,07573
Bi	-0,61712	**0,555844**	0,042269
Specific value	3,116917	1,123695	1,021545
Factor weight	0,519486	0,187282	0,170258

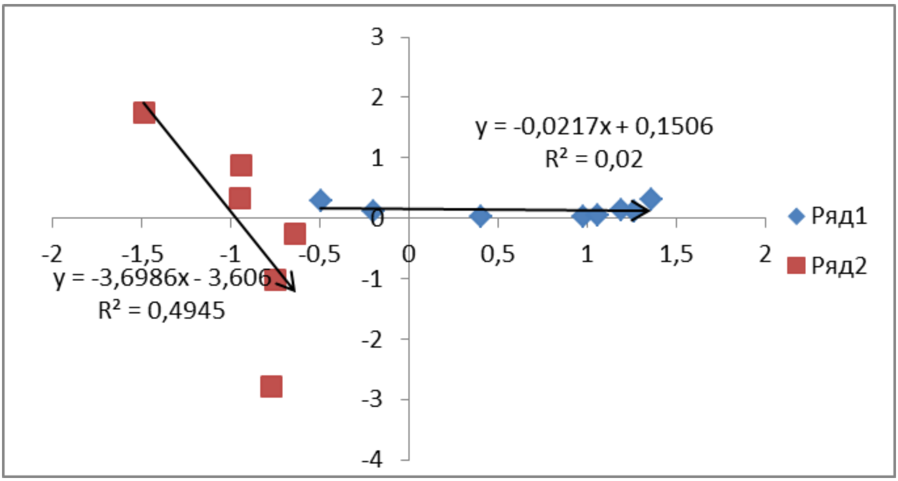

Figure 2. F_1 and F_2 on factor analysis results

It can be concluded from the materials presented above that the elements are grouped in factors or geochemical associations comparable to the mineral paragenesis of the main ore deposition stage. According to M.D. Belonin et al. (1982[41]), this grouping is confirmed by the correlation coefficient between geochemical and mineral properties, factor importance and major ore elements.

The following are considered element-indicators for various factors: 1- Zn, Cu, Co and Ni - for the constituent factor of host rocks; 2 - Cu, Mo, Co and Ni - for geochemical specialization and primary magma type factors; 3 - Mo - for the depth factor; 4 - Pb, Mo, Zn and Cu for ore-bearing factor.

According to the information by V.M.Babazade et al. (1990[26]), and V.G.Ramazanov (1993[30]), impregnated and impregnated-veinlet type stockwork ore masses have developed in the Goshgarchay porphyry copper deposit. Vein-type ore masses have limited development, are represented by quartz and carbonate veins smeared with pyrite, chalcopyrite and molybdenite minerals, located in shear and hydrothermal alteration zones.

The stockwork-shaped ore masses cover the central part of the deposit and are adapted to the apical and outer part of the porphyry intrusive, more precisely, to its endo- and exocontact zone. Ten ore columns with 0.3% on-board quantity of Cu on the surface within the stockwork were separated by V.G.Ramazanov (1993[30]). Enriched areas are gradually merged and form single ore mass with a complex morphology-stockworks. According to the information by V.M.Babazadeh et al. (2005[42]), the existence of two ore horizons, which were enriched with copper mineralization in the deposit and inclined towards the north (15-30˚), was determined. The upper ore horizon has a considerable thickness and comes to the surface, while the lower ore horizon lies at a depth of 80-150 m below the surface.

The mineral composition of the Goshgarchay deposit is relatively simple and the following ore minerals have been found:

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[41] Белонин М.Д., Голубева В.А., Скублов Г.Т. Факторный анализ в геологии / Москва; Недра, - 1982.- 269 с.

[42] Минерально-сырьевые ресурсы Азербайджана (условия формирования, закономерности размещения, научные основы прогнозирования) / Ответственный редактор В.М. Баба-заде – Баку: Озан, – 2005. – 808 с.

pyrite, chalcopyrite, sphalerite, arsenopyrite, melnicovite-pyrite, marcasite-pyrite, marcasite, cobalt-pyrite, enargite, galena, chalcosine, covelline, malachite, azurite, limonite, etc.

According to a number of researchers (Babazadeh et al., 1990[26]; Ramazanov, 1993[30]), the formation of the Goshgarchay porphyry copper deposit took place in two stages: hydrothermal-metasomatic ores were deposited in the first stage, and polymetallic ores were deposited in the second stage. According to the composition of copper minerals in the deposit, the following types of ores are distinguished: 1) pyrite-chalcopyrite and chalcopyrite-pyrite; 2) pyrite-bornite-chalcopyrite; 3) dull ores (pyrite)-chalcopyrite; 4) chalcocine-chalcopyrite; 5) native copper. The more common types are chalcopyrite-pyrite and pyrite-bornite-chalcopyrite ores.

Geological-genetic model of porphyry copper deposits of Goshgarchay ore-magmatic system. One of the main factors in the formation and location of porphyry copper deposits is their relationships with certain magmatic complexes. From this point of view, the Murovdag anticlinorium reflects the intrusive-volcanic association characterized by andesite volcanism and represented by the gabbro-diorite-granodiorite formation of granitoid intrusive magmatism (Baba-zadeh et al., 1990[26]).

The geological-genetic model of the porphyry copper deposits of the Goshgarchay ore-magmatic system is based on geological factors such as the geological characteristics of the host rocks and fault structures, the morphology and occurrence characteristics of intrusive complexes, the mineralized phases of intrusives (porphyry, granitoid), metasomatic alterations and their formational diversity, the morphology and boundaries of ore masses, and thermobarochemical conditions of the mineralization process, stages of mineral formation and mineral associations (intermediate zone-pyrite+chalcopyrite; inner zone and core-pyrite+chalcopyrite+ molybdenite), successive concentric zonal alterations, ore-metasomatic zoning, segregation of sulphide mineralization, eruptive breccias and features of erosion section (Mansurov, 2013[43]).

According to the analysis of existing geological data (structural, magmatic, geophysical, geochemical, etc.) and the results of multi-year studies on the Goshgarchay ore-magmatic system, one of the main features for the building of the geological-genetic model of porphyry copper deposits is the direct connection of the metasomatic alteration zonation of the host rocks with rich ore fields. More obvious examples are potassic, quartz-sericite secondary alterations, extended argillization and propylitization. Usually, hypogene expanded argillite alteration is formed relatively late in the formation process of the porphyry system (Sillitoe, 2010[44]; Bean et al., 1984[45]).

The developed model provides ideas not only about the lateral location of the metasomatic zone and sulphide mineralization in the ore-bearing intrusive, but also about the vertical determination of the intrusive and mineral association (Sillitoe, 2000[46]), and touching on the proportions of metasomatic zones (from the center to the edges and from the bottom to the top: kalifeldspathization, biotitization, sericitization, propylitization, argillisitization, and silicifivation), it was also stated that most ore-bearing porphyry stocks were formed at a depth of 0.6-4.0 km from the surface.

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[43] Мансуров, М.И. Геолого-генетическая модель Гошгарчайской рудно-магматической системы Муровдагского поднятия (Малый Кавказ, Азербайджан) // – Баку: Известия Национальный Академии Наук Азербайджана. Науки о Земле, – 2013. № 4, – с.16-22

[44] Sillitoe, R.H. Porphyry Copper System // Society of Economic Geology, – 2010. v.105, – p. 3-41

[45] Бин Р.Э., Титли С.Р. Медно-порфировые месторождения. В кн.: Генезис рудных месторождений / Р.Э. Бин, – Москва; Мир, – 1984, – с. 245-321

[46] Sillitoe, R.H. Gold rich porphyry deposits: descriptive and genetic models and thiir role in exploration and discovery // Gold in SEG Revies, – 2000. v. 13, – p.313-345

The use of thermobarogeochemical methods ensures the sequence of fluid inclusions in the minerals of magmatic formations of ore-magmatic systems and various mineral associations, parameters such as temperature, salinity, gas content and metal content of inclusions, as well as the recovery of fluid inclusions and the determination of the nature of mineralization (Roedder, 1971[47]).

The physico-chemical conditions of formation of porphyry copper deposits of the studied ore-magmatic system can be discussed by analyzing gas-liquid inclusions. Inclusions were studied by applying homogenization and decrepitation methods in minerals such as quartz, galena, sphalerite and chalcopyrite, which accompany at all stages of mineral formation (Mansurov, 2021[48]).

According to the obtained microthermometric data, the initial average salinity of the fluid inclusions in the quartz mineral was 5% NaCl and the temperature was 366°C, and in the later stages of mineralization, the temperature of the fluid inclusions reached an average of 278°C, and the average salinity was 5.2% NaCl (Fig. 3).

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[47] Roedder E. Fluid inclusion studies on the Porphyry-type ore deposits at Bingham, Utah, Butte, Montana and Climax, Colorado // Economic Geology, – 1971. v.66, N. 1, –p. 98-120

[48] Мансуров М.И. Особенности размещения и условия формирования Кошкарчайского медно-порфирового месторождения (Малый Кавказ, Азербайджан) // Вiсник Киiевського нацiионального унiверситета iменi Тараса Шевченка, Геология, 2021, № 2 (93).с. 41-52, DOI: http: // org/ 10.17721/1728-1713.93.05

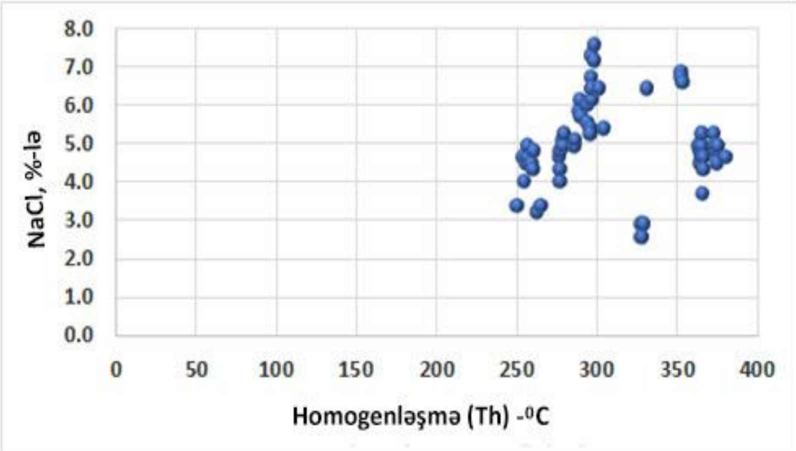

Figure 3. Equivalent salinity diagram between homogenization temperature and NaCl % on quartz minerals

It was determined that the formation of the deposit began with the occurrence of primary quartz veins at a depth of 2.5-3 km under temperature conditions of 400-250°C. Porphyry copper ores were formed in a post-magmatic hydrothermal environment at a temperature range of 365-200°C at a depth of 1-2 km.

According to the above-mentioned materials, it is possible to observe the ore-magmatic zonation of the Goshgarchay ore-magmatic system surrounded by the supposed quartz core and pyrite "shirt" (Fig. 4; 5). In order to reveal the source of ore-forming solutions for the stages of mineralization of the porphyry copper deposits of the Murovdag ore region, the data on the isotopic compositions of sulfur and sulfides and the data of the gas phase of hydrotherms with ore quartz-pyrite-chalcopyrite and quartz-chalcopyrite mineralization were used (Bean et al., 1984[44];

Gavrilyuk et al., 1997[49]; Grinenko, 1974[50]). Sulfides that complete the mineralization process in the quartz-sphalerite-chalcopyrite stage are characterized by significant enrichment with heavy sulfur isotopes (δS^{34}). At this time, the range of variation changes in the range of δS^{34} + 0.1‰ + 0.7‰.The value of $\delta^{34}S$ = +10.0 ‰ indicates that pyrrhotite is a product of placer halos of sulfide mineralization on the flank of the stockwork. The sulfur isotopic data (+0.1‰ to +0.7‰) of the sulfides correspond to the range of significantly heavier value ($\delta^{34}S$ = 0 ± 35‰) of described magmatic sulfur. Enrichment with heavy sulfur isotopes can also occur during the hydrolysis of sulfides on host sedimentary rocks (Omoto, 1986[51]; Taylor, 1986[52]).

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[49] Гаврилюк, П.С., Магриби, А.А. Изотопно геохимические особенности сульфидных и сульфатных руд месторождений Лок-Гарабахской зоны Малого Кавказа (Азербайджан) // – Баку: Труды Институт Геологии Академии Наук Азербайджана, – 1997. № 26, – с. 109-118

[50] Гриненко, Л.Н. Геохимия изотопов серы / Л.Н. Гриненко, В.А. Гриненко – Москва; Недра, – 1974. – 274 с.

[51] Omoto, H. Stable isotope geochemistry of ore deposits // Reviews in Mineralogy and Geochemistry, – 1986. v. 16, – p.491-560

[52] Taylor, B.E. Magmatic volatiles: Isotopic variation of C, H and S // Reviews in Mineralogy and Geochemistry, – 1986. v. 16, – p.185-225

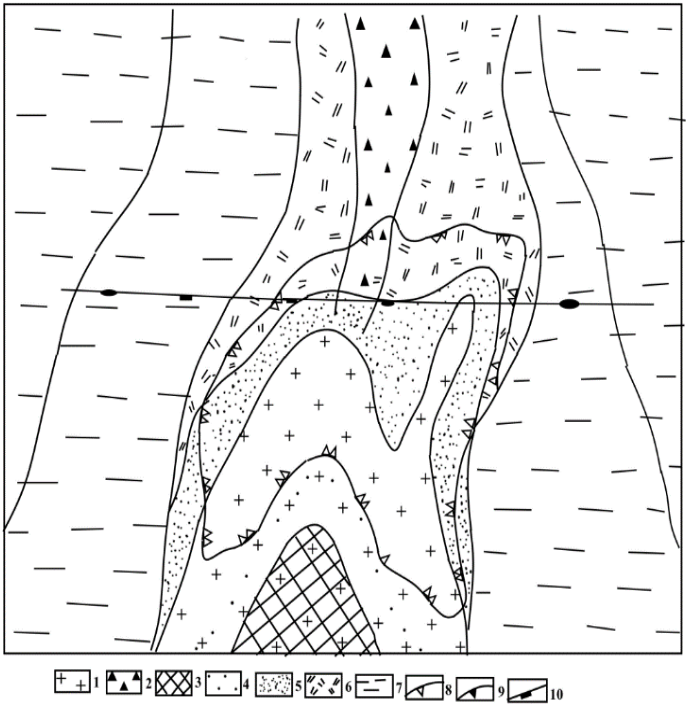


Figure 4. Model of Goshgarchay porphyry copper deposit in vertical section: 1 - granodiorites; 2 - explosive breccias; 3 - quartz core zone; 4 - presumed kalifeldspathization zone; 5 - silicification, sericitization and chloritization zone; 6 - propylitized rocks; 7 - ore-bearing porphyry intrusive; 8 - intrusive pyritization halos; 9 - industrially significant mineralization boundary; 10 - section line

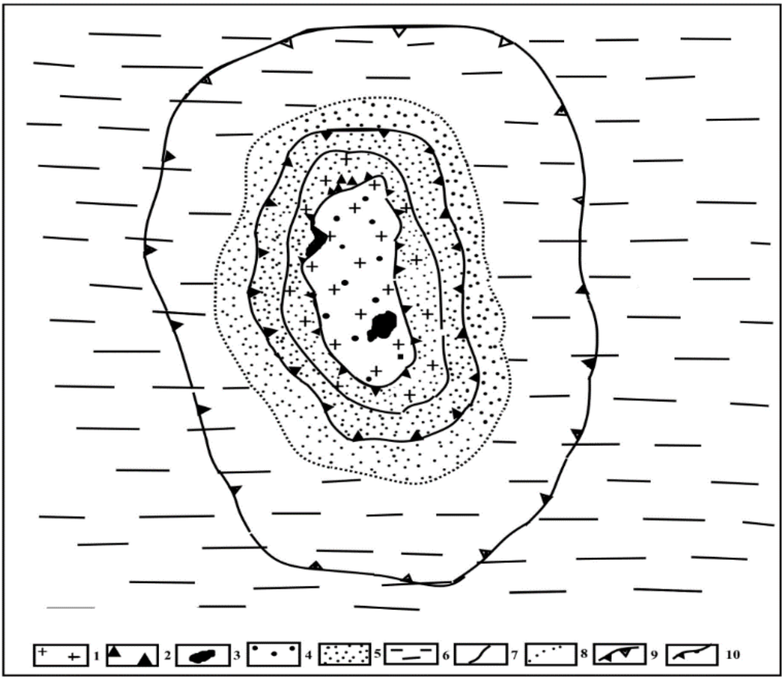


Figure 5. Model of Goshgarchay porphyry copper mineralization in horizontal section: 1 - ore porphyry intrusive; 2 - breccia pipe; 3 - quartz core; 4 - presumed kalifeldspathization zone; 5- silicification, sericitization and chloritization zone; 6 - argillization zone; 7 - propylitized rocks of intrusive ledge; 8 - border of intrusive pyritization halos; 9 - border of industrial mineralization; 10 - state of the erosion section

Geological-genetic model of Gehmana ore-magmatic system. The Mehmana ore-magmatic system is located in the southeast of the Lok-Karabagh zone and is adapted to the junction of the Agh-dam anticlinorium and the Delidag-Mehmana transverse uplift. Here, different types of sulphide deposits are spatially related to each other. In one case, porphyry copper mineralization is overlain by later sulfide mineralization. In the second case, the last one forms an industrially important vein-type mineralization by forming a concentration slightly outside (Geology of Azerbaijan, Vol. 6, Mineral resources, 2003[6]).

Middle Jurassic sediments are more widespread in the geological structure of the region, and fault structures play an important role in the structure. Most of them are hidden and determined based on remote data.

Ore masses are classified as vein type according to their structural-morphological characteristics and internal structure. All the veins lie between Bathonian volcanogenic and volcanogenic-sedimentary rocks with steep northwest and southeast dip. The shape and thickness of the ore veins are closely dependent on the lithological composition of the host rocks. The quartz-galena-sphalerite mineral association is widely developed in the veins, and galena predominates over sphalerite in quantity.

Various minerals are involved in the mineralogical composition of ores. Ore minerals form veinlets in veins, isometric shaped lens-like aggregates, as well as impregnations and pockets up to 15-20 cm in size.

The main ore minerals of the veins are considered to be galena and sphalerite, galena predominates over sphalerite. A small amount of pyrite and chalcopyrite is developed. The minerals such as tennantite, bornite and chalcocine are rare. Limonite, a small amount of cerussite, anglesite, malachite and azurite were developed at a shallow depth after oxidation (Khalilova, 1972[53]).

The following hypogene mineralization stages, which were separated by tectonic breaks, have been distinguished by researchers in the deposit: 1) pyrite-calcite; 2) pyrite-chalcopyrite-sphalerite; 3) sphalerite-galena; 4) galena-calcite; 5) calcite (Zaitseva et al., 1964[54]).

Elements such as Au, Ag, Cd, In, Se, Tl, Te, Ga and Bi are observed in ores. Au and Ag are participated in many ore veins

[53] Халилова Т. Минералогия Мехманинской группы свинцово-цинковых месторождений / Т. Халилова. – Баку: Элм, – 1972. – 76 с.

[54] Зайцева Л.В., Рафибейли Р.Х. Структурные особенности Мехманинского рудного поля и стадийность рудообразования / В кн.: Закономерности размещения полезных ископаемых, Москва; Наука, т.7, –1964. – с.64-79

and certain regularity is observed in determining their amount. According to N. Ilyasov (1974[55]), Au is observed in low amounts in galena and sphalerite. A high amount of Au is observed in ore veins with a high amount of chalcopyrite. Native Au was observed in chalcopyrite-pyrite, sphalerite-chalcopyrite, specific sphalerite, magnetite-sulfide ores.

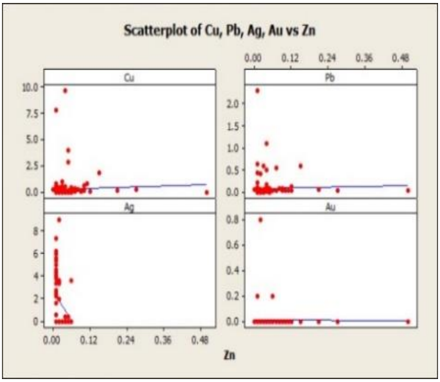
The characteristics of dependence between the main ore elements in different types of ores of the deposit have been determined. The dependence relationship of Pb and Zn elements with Cu, Ag, Au elements and at the same time between each other is given. As you can see in the diagram, the main part of the point clouds is concentrated around the regression line, at the beginning of the line, and a small part is concentrated at the edge of the line. Point clouds are concentrated along the vertical line in the dependency diagram of Zn, Pb and Ag. It can be seen from the diagram that there is a significant close correlation between these elements.

As can be seen from Figure 6, the distribution of points does not exactly match the regression line. The distribution of points in the right half of the linear regression curve is uneven. Except for the dependence of Cu – Ag, point clouds are mainly concentrated along the regression line, especially at the beginning of the line in the dependency diagram of Cu on other elements. Ores with a high amount of Cu and a low amount of Zn are classified as oxides, and they are localized near the top of the ore mass where native Cu is found (Dobrovolskaya, 1989[56]). A different state was obtained compared to others in the dependency diagram of Au on other elements. So, there was a discrepancy in the distribution of points, the point clouds were not aligned along the regression line but along a vertical section. The point clouds are almost distributed equally along the regression line and on the edges in the point de-

[55] Ильясов, Н.Р. Геохимия золота и серебра в месторождениях и рудопроявлениях в одном из рудных полей Малого Кавказа / автореферат диссертации кандидат геолого-минералогических наук, Баку: – 1974. – 38 с.

[56] Добровольская, М. Свинцово-цинковое оруденение (рудные формации, минеральные парагенезисы, особенности рудообразования) – Москва; Наука, – 1989. – 216

pendency diagram of Ag between Zn, Pb, Cu and Au (Fig. 7). The main accumulation area of the points corresponds to the primary sulphide ores of the deposit (Mansurov et al., 2021[57]).



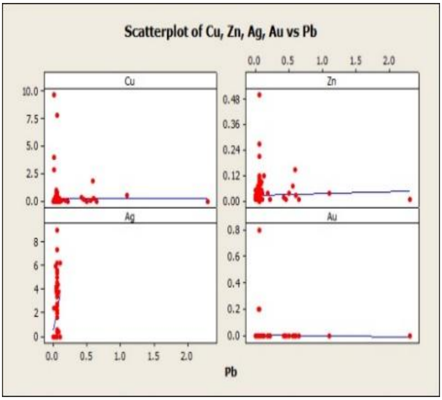


Figure 6. Graph of linear dependency of Zn and Pb with other ore elements (Cu, Ag, Au) in different types of ores on the Mehmana deposit

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[57] Mansurov M.İ., B.H.Galandarov, M.H.Safari, V.M.Karimov, U.I.Karimli Geochemical features of the distribution of ore elements in the polymetal ores of Mehmanian deposit (Azerbaijan part of Lesser Caucasus) // Известия вузов Северо - Кавказский региона. Серия естественных науку, 2021, № 2, с. 88-98

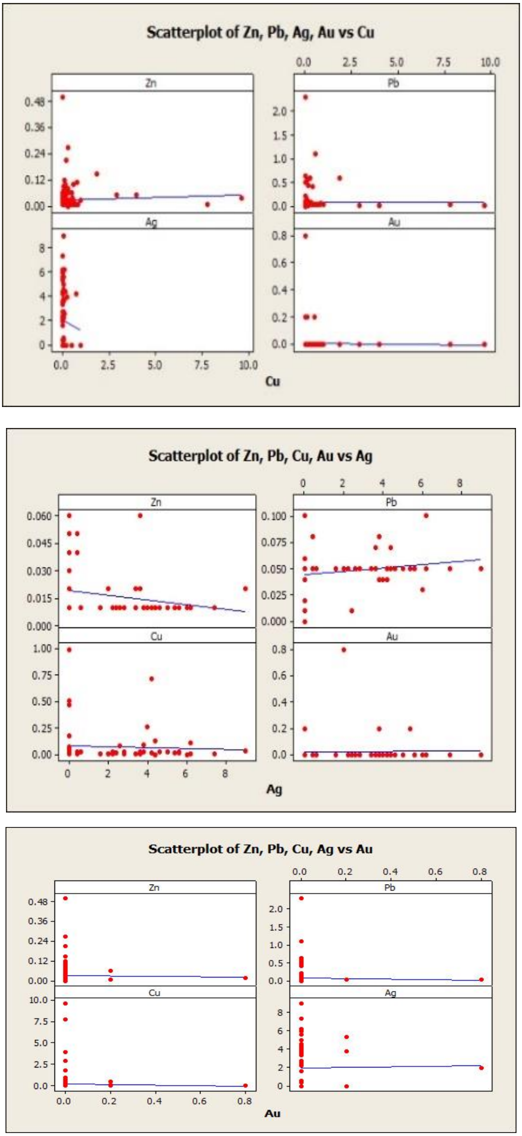

Figure 7. Graph of linear dependency of Cu, Au and Ag with other ore elements (Zn, Pb) in different types of ores of Mehmana copper-polymetallic deposit

According to the linear dependency diagrams between the main components (Pb, Zn, Cu, Ag, Au) in different types of ores on the Mehama field, it can be stated that the determination of the majority of chemical elements is related to a positive correlation. This suggests that they all formed as a result of a single geochemical process, and that at least three different mineral associations are participated in the polymetallic ore masses: 1) primary sulfide ores; 2) oxide ores; 3) sulphide ores significantly enriched with Pb (Balakishiyeva, 1966[58]; Kalandarov, 2010[59]).

Gizilbulag gold-copper-copper deposit. The geological-structural position of the deposit is determined by its adaptation to a small section of the junction zone of the Karabakh and Aghdam anticlinoriums with the Khojavand synclinorium, and the deposit is adapted to the Drambon volcano-dome structure (Babazadeh and others, 1998[60]).

Gold mineralization within the Gizilbulag deposit was represented by ore masses of different morphological types: lenticular, stockwork, crushed mineralization zone, veinlet zone, or a combination of the abovementioned morphological types. The morphological characteristics of ore masses depend on the nature of the fracture faults with which they are aligned in many cases. According to the morphostructural structure and boundary of the ore masses, three ore masses have been observed within the deposit. *The first ore mass* has a rather complex shape and is localized in the northeastern flank and near dome part of the biclonal structure between the sour lavas and tuffs of the Late Bajocian neck facies. *The second ore mass* has no access to the surface, is located in the southeastern part of the deposit and

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[58] Балакишиева, Б. Геохимия кадмия в свинцово-цинковых месторождениях Азербайджана / В кн.: Геохимия редких элементов Баку: Издательствво Академии Наук Азербайджанская ССР, – 1966. – с. 46-69

[59] Каландаров, Б.Г. Полиметаллические рудные формации Малого Кавказа / автореферат диссертации доктора геолого – минералогических наук: / – Баку: – 2010. – 49 с.

[60] Баба-заде, В.М., Мамедов, З.И. Особенности структуры Гызылбулагского рудного поля // Вестник Бакинского Университета. Серия естественных наук, – Баку: – 1998, № 4, –с. 107-117

surrounds a dome-shaped structure. *The third ore mass* is located in the north-west, uplifted part of the deposit and has a complex lenticular shape on the surface (Mineral resources of Azerbaijan, 2005[37]; Huseynov, 1991[61]).

Lateral and vertical zoning was observed in the determination of gold and more stable ore-indicator elements in the Gizilbulag field. Zn – Pb – Cu – Ag – Au zonation was observed in the lateral zoning according to the thickness of ore masses (from lying side to dependent side). An increase in Cu and Au is observed in a constant amount of Ag. According to the zoning index of the elements, the sequence Ag – Cu – Au – Zn – Pb stands in their vertical order. The amount of Au and Cu remains constant throughout the depth, while the amount of Pb and Zn changes and increases towards the lower horizons of the deposit, and on the contrary, the amount of Ag decreases. This shows again that there is no positive correlation between Ag and other indicator elements. In general, besides gold-copper mineralization, it can be expected native lead-zinc layers and the presence of telescoping polymetallic ores on them in the lower horizons of the deposit (Mammadov, 2005[62]). Behavioral characteristics of the elements were studied for the entire ore mass, and the elements were divided into two groups by R (5%) cluster analysis: 1 – Au, Cu and Ag; 2 – Zn and Pb. A closer relationship was determined between Au and Cu, Au and Ag, Ag and Cu in the first group, and Pb and Zn in the second group (Mansurov et al., 2020[63]).

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[61] Гусейнов, Д.А. Рудоносность субвулканических образований Гызылбулагского рудного поля (Малый Кавказ) /афтерефарат диссертации кандидат геолого –минералогических наук / – Баку, – 1991. – 23с.

[62] Мамедов, З.И. Геолого-структурные особенности формирования и закономерности размещения медно-золотых руд Гызылбулагского месторождения / автореферат диссертации кандидат геолого-минералогических наук / – Баку, 2005, – 24 с.

[63] Мансуров М.И., Каландаров Б.Г., Керимли У.И., Гусейнов А.И.Распределение золота и сопутствующих рудогенных элементов в золото-медноколчеданных рудах Кызылбулагского месторождения (Малый Кавказ, Азербайджан) // Известия вузов Северо - Кавказский региона. Серия естественных науку, 2020, № 3, с. 51-59

Geological-genetic model of the Demirli ore-magmatic system. The Demirli porphyry copper deposit among the abovementioned porphyry copper deposits is considered more interesting and promising due to its geological characteristics. The deposit is structurally located in the northeastern wing of the Aghdam anticlinal fold, which is complicated by the Gulyatag depth fault. The main part of the deposit area is represented by quartz diorite-porphyrite, which is the outer facies of Mehmana granitoid intrusive, as well as rhyodacites and their tuffs (Babazade and others, 1990[25]).

Ore mineralization in the porphyry copper deposits and occurrences of the Demirli ore-magmatic system was represented mainly by impregnated-veinlet copper and small amount of impregnated and vein-type copper-molybdenum mineralization. Ore and non-ore veinlets of different thicknesses and orientations together with dense sulfide impregnations form stockworks with different morphology. The observation of mineralization within these stockworks is uneven. Impregnated and vein-type mineralizations are locally distributed in separate locations, and Cu content is high in veins and varies in a wide range (0.2-3.34%) in mineralization zones, averaging 0.5–1.0% over the ore interval. The amount of Mo is relatively low and varies in the range of 0.002-0.008%. Veins usually contain a certain amount of Au and Ag (Babazade and others, 1990[25]).

Porphyry copper ores are distinguished by the variety of mineral compositions, and about 40 minerals have been observed in the composition of the ores. Among the hypogene minerals, the main ore minerals are pyrite, chalcopyrite, and relatively less widespread ones are bornite, chalcosine, digenite, rutile and muschketowite. Rare minerals include sphalerite, galena, dark ores, native gold, renierite, crednerite, tellurobismuth, sylvanite, altaite, marcasite, and pyrrhotite. Quartz, sericite, gypsum, calcite, bassanite, etc. have been developed among the vein minerals (Baba-zadeh, 1990[25]). The main hypergene minerals in the oxidation zone are iron hydroxides, chalcocine, malachite, azurite and native gold. The main useful component of ores is Cu. Besides these, ores contain Mo, Au, Ag, Cu, Re, Se, Te, Bi and other useful components. Localization of porphyry copper ores occurred in several productive mineralization phases and corresponding mineral associations. According to the time of formation, the earlier stage of mineralization is considered to be magnetite-sericite-quartz and pyrite-quartz mineral association, which form mineral complexes up to productivity. Chalcocine-bornite-chalcopyrite-quartz-carbonate and sphalerite-galena-gold-rare metal mineral associations were deposited during the second productive mineralization stage (Mineral resources of Azerbaijan, 2005[37]). Native gold, which are represented by morphologically irregular, skeletal formations, crystalline segregations and dendrite forms, was also found in the ores (Grabezhev et al., 1995[64]).

Within the studied ore-magmatic system, the secondary quartzite, argillite and propylite formation of metasomatites is divided into locally developed quartz-muscovite and muscovite-quartz-greisen facies. The formation of greisens is associated with the activity of hydrothermal solutions of small intrusives and has a local character (Kerimov, 1965[34]). The inner zone of the metasomatic column, i.e., the zone of more intense alteration locally located along the path of intense circulation of solutions, is typical for wallrock alterations (Rusinova et al., 2003[65]).

The more widely developed secondary quartzite formation in the deposit boundaries is characterized by monoquartzite, quartz-sericite, quartz-sericite-chlorite and quartz-kaolinite varieties, and these facies were formed by intrusive and volcanic rocks. Argillitic metasomatites were mainly formed due to primary metasomatites (secodary quartzites) and intrusive rocks.

The geochemical zonation of elements in Demirli ore-magmatic system is gradually occurred in the following sequence:

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[64] Грабежев, А.И., Коробейников, А.Ф., Молошаг, В.П. Золото в медно-порфирового месторождения Урала // Геохимия, – Москва; – 1995. № 10, – с. 1465-1471

[65] Русинова О.В., Русинов В.Л. Метасоматический процесс в рудном поле Мурунтау (Западный Узбекистан) // – Москва: Геология рудных месторождений, 2003, т. 45, №1, с. 75-96

(Fe) → Fe+Cu (Mo) → Cu+Fe→Fe+Pb+Zn (Ag+Au). As you can see in this sequence, pyrite is direct in nature and is observed in all zones. According to the conducted analysis, the correlation of ore elements in several deposits of the ore region suggests that metals such as Cu, Mo, Au and Ag were transported together with the juvenile fluids (Titley et al., 1984[66]).

The results of the study of liquid-gas inclusions in minerals such as quartz, calcite, barite, chalcopyrite, molybdenite, magnetite by homogenization and decrepitation methods were used to restore the physical and chemical conditions of the formation of porphyry copper deposits within the limits of Demirli ore-magmatic system (Redder, 1978[67]).

Microscopic analysis of the internal structure of mineral inclusions allows distinguishing three types of inclusions: 1) multiphase; 2) two-phase; 3) single-phase. Multiphase inclusions were represented by the combination of liquid+gas+mineral inclusions. The latter is represented by ore and non-ore minerals. More pyrite, chalcopyrite, hematite are mentioned among the former, and halite, sylvine, calcite and anhydrite among the latter (Ramazanov, 1993[28]).

Two-phase inclusions were represented by combination of liquid + gas, liquid + mineral inclusion and gas + mineral inclusion. Single inclusions were represented by either gas or liquid phase. A constant temperature indicator is typical for pyrite. It is 210-230˚C as in the first stage of mineralization. The decrepitation temperature of molybdenite from this stage is relatively high and is 390-450˚C (Fataliev, 1995[68]). A gradual decrease in the crystallization temperature of vein minerals is

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[66] Титли, С.Р. Медно-порфировые месторождения. В кн.: Генезис рудных месторождений / С.Р.Титли, Р.Е.Бин – Москва: Мир, –.1984. т.1, –.с. 245-333

[67] Рёддер, Э. Флюидные включения в минералах / Э. Рёддер. –Москва: Мир, –1978. –360 с.

[68] Фаталиев, Р.А. Геологические особенности медно-порфирового оруденения Агдамского антиклинория Малого Кавказа и условия его формирования / автореферат диссертации кандидат геолого-минералогических наук / – Баку, 1995. – 25 с.

observed from the initial stage of ore deposition to the late stage in the Demirli ore-magmatic system.

Quartz deposited at 130-110˚C in the quartz-pyrite-chalcopyrite association, while the decrepitation temperature of chalcopyrite varies in a wide range (120-230˚C). This is explained by the presence of two generations of chalcopyrite in the mineralization stage. The II productive stage of the ore deposition process is composed of two complex mineral associations: chalcocine-bornite-chalcopyrite-quartz-carbonate and sphalerite-galena-gold-rare metal. Calcite and barite among the minerals of this stage were studied and the decrepitation temperature was determined in the range of 70-300˚C. The sedimentation temperature of galena and sphalerite minerals was determined in the range of 200-250˚C (Baba-zadeh et al., 1990[25]; Fatalieyv, 1995[57]). So, according to the results of mineral homogenization and decrepitization studies, it can be concluded that the ore deposition process in the porphyry copper deposits of the Demirli ore-magmatic system took place in the temperature range of 450-110˚C.

The fourth defended point. *Predictive and search models of promising ore fields, search and predictive criteria for the revealing new ore deposits and occurrences.*

According to a number of researchers (Avdonin et al., 2007[69]; Korobeinikov, 2009[70]; Kurbanov, 1984[71]), the following are considered the main elements of the search and predicted model: 1) the association of rocks and ore formations that

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[69] Авдонин В.В., Ручкин Г.В., Шатагин Н.Н. (и др.). Поиски и разведка месторождений полезных ископаемых / Москва: Академический проект, – 2007. –540 с.

[70] Коробейников, А. Прогнозирование и поиски месторождений полезных ископаемых / Томск: Томского политехнического университета, – 2009. – 253 с.

[71] Курбанов, Н.К. Геолого-генетические предпосылки прогноза и поисков месторождений цветных и благородных металлов в альпийской вулканогенной эвгеосинклинали Малого Кавказа /Труды ЦНИГРИ, вып. 189, Москва, 1984, с. 3-36

determine the structural and paleotectonic state of the deposits, their parts in a regular combination (phase, facies, etc.); 2) the concentration level and presence of indirect indicators (mineralogical, geochemical, geophysical) separated based on the use of a given type of mineralization, mineralogical, geochemical and geophysical search methods; 3) sum of direct prospecting indicators indicating the occurrence of a given type of mineral; 4) changing the characteristics of the elements of the model depending on the geological situation.

Special importance was given to the study of the exact structural conditions in the development of additional search indicators and criteria that create favorable conditions for the segregation of favorable specific geological structures, which is suitable for geological-exploration works with the search for ore masses of porphyry copper, copper-pyrite, copper-polymetallic, copper-gold-pyrite, etc. genetic type of deposits without wedging out. At this time, the localization characteristics of mineralization within the Murovdag and Aghdam ore regions were analyzed for the study of specific localization conditions of mineralization in different geological-structural conditions in standard objects. According to the analysis of mineralization maps on the scale of 1:100,000-1:50,000 of ore-magmatic systems and some ore junction for various genetic types of mineralization and numerous actual materials, search criteria were developed and divided into regional and local types. These criteria can be applied as search criteria for the revealing mineral deposits in the region.

The main structural elements that determine the position of ore-magmatic systems are considered to be high fracture zone, dyke areas, intrusive masses, including large faults, etc. The adaptation of the vast majority of hydrothermal deposits and occurrences to these fractures suggests that they are important structures that control the determination of porphyry copper, copper-gold-pyrite, copper-polymetallic, etc. mineralization. These fault structures play the role of branched structures of the deep

Gadabey-Dalidagh lineament zone (Mansurov, 2018[72]).

Second-order faults, especially their junction with northwest-oriented faults, play no small role in the localization of ores. More favorable conditions for the localization of mineralization are concentrated in junctions of lithological factors and fracture zones. The high fracture zone is accompanied by a series of parallel dykes (especially porphyry dykes) of different composition and age.

The dykes have undergone intensive metasomatism (propylitization, silicification, chloritization) due to the circulation of hydrothermal solutions, and changes of geological formations are observed in their area. Mineralogical features include the generation of pyrite and chalcopyrite, as well as larger amounts of sulfides. The connection zones of linear, annular and arched depth structures of different genetic nature, which were obtained with the help of Landsat and ASTER satellite data, aerospace and space images, act as structural criteria.

A free search model was built for each hierarchical level of the predicted geological areas within the limits of Murovdag and Aghdam anticlinoriums, and the search- and predicted criteria of this model can be used in the end. Processing of each search model of different hierarchical order and search and predicted criteria are performed according to certain complex methods here. In order to evaluate the prospects of endogenous mineralization of the region, we used the direct and indirect generalized search indicators of porphyry copper, copper-polymetal, copper-pyrite, copper-gold-pyrite, etc. genetic type mineralizations, as well as data of geophysical and geochemical (primary, secondary and concentrate) anomalies in the development of the search-pognosis model.

According to the above-mentioned geological criteria, the following main principles of searching for complex ores in

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[72] Мансуров М.И. Факторы контроля размещения и локализации медно-порфирового оруденения зоны сочленения Муровдагского и Агдамского антиклинориев (Малый Кавказ) // Вестник Бакинского Университета. Серия естественных наук, 2018, № 2, с.71-80

Murovdag and Aghdam anticlinoriums, assessing prospective areas and predicting resources can be stated (Baba-zadeh et al., 2011[73]; Pavlova, 1978[74]; Mansurov, 2013[75]): 1) re-assessment of the regularity of location and metallogenic profile of the main industrial types of complex ores of the contact belt of Murovdag and Mehmana granitoid massif; 2) the role of block structure in localization of porphyry copper and complex ores; 3) revealing ore controling zones (the occurrence of magmatism, hydrothermal processes, the presence of ore occurrences of various metals, etc.) and ore-bearing structures that determine the position of industrially important ore fields, deposits and ore occurrences; 4) determination of the role of the regular development of folding and faulting tectonics of the region and segregation of the ore-controlling role of northwest-oriented structures; 5) the location of porphyry copper, copper-polymetallic and copper-gold-pyrite mineralization in the anticlinorium boundaries formed by thick volcanites; 6) adaptation of mineralization to Bajocian rhyolite, andesite and dolerite porphyrite and their pyroclastolites; 7) controlling mineralization by depth fractures, large transverse upland and fault zones, which act as ore-bearing and ore-controlling channels; 8) genetic or paragenetic relationship of mineralization to Jurassic granodiorites; 9) the presence of northwest, north-northeast and northeast oriented fault-deformation systems, which are considered favorable for mineralization localization; 10) adaptation of mineralization to the development zone of the dyke complex; 11) presence of pre-

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[73] Баба-заде В.М., Мамедов М.Н., Ахмедов Д.М. (и др.) / О перспективах выявления новых рудных месторождений и проявлений в пределах Карабахского поднятия (по данным дистанционных исследований) // Вестник Бакинского Университета. Серия естественных наук, Баку: 2011, № 4, с.138-152

[74] Павлова, И. Медно-порфировое месторождения (закономерности размещения и критерии прогнозирования) / Ленинград: Недра, – 1978. – 276 с.

[75] Мансуров, М.И. Поисково-прогнозные критерии выявления перспективных участков и новых типов оруденения Муровдагского горст-поднятия // Баку: Вестник Бакинского Университета. Серия естественных наук, – 2013. №4, – с.107-118

mineralization and post-mineralization wallrock metasomatic alterations and their facies diversity; 12) presence of connection zones of linear, annular and arched depth structures of different genetic nature; 13) revealing hydrothermal-metasomatic alteration and mineralization zones with indirect search indicators for discovering promising areas for ore-bearing with the help of satellite data (Landsat, ASTER).

CONCLUSION AND SUGGESTIONS

1**.** The different directional fault structures with thrust and upthrust characteristics, especially the north-west and near-meridional faults, which give the Goshgarchay ore-magmatic system a block structure, are considered the main ore-controlling structures for the localization of porphyry copper mineralization within Goshgarchay ore-magmatic system.

2**.** According to the statistical analysis of the distribution of elements in the Goshgarchay ore-magmatic system, the elements in the host rocks are divided into three free groups: according to the first group: 1. Ag-Cu; 2. Bi-Cd-Pb; 3.Cr-Mo; according to the second group: 1. Al-Ca-Mn; 2. Mg-V-Sc-Ti; 3. Na-Sr-Ce-Ni-Fe-Zn-As-P; according to the third group: Ba-K-S.

3. Products of hypogene and hypergene mineral formation stages were involved in the mineralization process in Goshgarchay deposit, and ore elements are the product of one geochemical process. Three different mineral associations are observed in the deposit: 1) primary sulphide minerals; 2) oxidized ores; 3) primary sulphide minerals significantly enriched by products of hydrothermal ore-bearing solutions.

4. The main factor in determining the main ore components, its genetic and geochemical properties in the Goshgarchay ore-magmatic system is the presence of geochemical mineral associations that provide conditions for the localization of the development area of mineralization at different stages of the formation of the porphyry copper system.

5. The characteristics and regularity of the metasomatic zonation of the Goshgarchay ore-magmatic system show that it corresponds to the typical model of deposits of porphyry copper ore formations. The outer zone of altered rocks is represented by propylites, the intermediate zone by quartz-sericite and argillite metasomatites, and the inner zone by quartz metasomatites.

6. The ore masses of the Goshgarchay deposit are represented by the impregnated, impregnated-veinlet type of stockwork and vein type of ores according to their structural-morphological characteristics and internal structure. According to the composition of copper minerals, the following varieties of ores are distinguished: 1) pyrite-chalcopyrite and chalcopyrite-pyrite; 2) pyrite-bornite-chalcopyrite; 3) dark ores (pyrite)-chalcopyrite; 4) chalcocine-chalcopyrite; 5) native copper.

7. The formation of the Goshgarchay porphyry copper deposit began with the occurrence of primary quartz veins at a depth of 2.5-3 km at a temperature of 400-250°C. The formation of porphyry copper ores took place in a post-magmatic hydrothermal environment at a temperature range of 365-200°C at a depth of 1-2 km.

8. Different types of sulphide deposits within the Mehmana ore-magmatic system are spatially related to each other. In one case, porphyry copper mineralization is overlain by later sulfide mineralization. In the second case, the last one forms an industrially important vein-type mineralization by forming a concentration slightly outside.

9. Ore masses in the Mehmana copper-polymetallic deposit are attributed to the vein type according to their structural-morphological characteristics and internal structure and the main industrial useful components are Pb, Zn, Cu, Au, Ag, Cd, In, Bi, Hl, Tl, As, Sb, S, Se, Te and other elements. The deposit is divided into three levels according to the thickness of the ore veins: the lower level was mainly represented by Cu-Zn, the middle level was represented by Cu-Zn-Pb, and the upper level was mainly represented by Pb-Zn ores.

10. Mineralization in the porphyry copper deposits and occurrences of the Demirli ore-magmatic system is mainly

represented by impregnated-veinlet, a small amount of distributed impregnated and vein type of copper and copper-molybdenum mineralization, forming stockworks with different morphologies. Metasomatites are widely occurred in the development areas of porphyry copper mineralization and are represented by secondary quartzite, argillite and propylite formations.

11. The ore deposition process of the porphyry copper deposits of the Demirli ore-magmatic system is long-term and multi-stage. According to the results of homogenization and decrepitization studies, it can be concluded that the ore deposition process took place in the temperature range of 450-110˚C.

SUGGESTIONS

1. According to the analysis of mineralization maps on the scale of 1:100,000-1:50,000 of ore-magmatic systems and some ore junction for various genetic types of mineralization and numerous actual materials, search criteria were divided into regional and local types, and these criteria can be used as a search for new ore deposits and occurrences in the region.

2. It is proposed to make geological-structural, prediction-metallogenic and prediction-assessment maps, taking into account the main geological elements of the deposits and ore occurrences, as well as search factors and indicators of mineralization areas and zones.

3.In order to monitor hidden areas of ore masses that do not come to the surface in the boundaries of the deposits, especially on their sides, it is proposed to carry out inclined 200-250 m deep and 300-350 m deep structural-search wells.

4. The results of the analysis of samples taken from surface and underground mountain excavations, hydrothermal-alteration zones, geological-exploratory wells show that the limits of ore-magmatic systems are promising, and it is proposed to continue search-assessment and precise exploration works in these areas in order to increase the mineral raw material base of the country in the future.

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Address: Az1148, Baku, Z. Khalilov Street. 33, BSU, Faculty of Geology

Phone: 012 539 09 81
E-mail: geologiya@bsu.edu.az

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