

Geological framework and metallogenic evolution of the Demirli Cu-Mo porphyry system, Lesser Caucasus, Azerbaijan

Namad Pashayev¹ , Saida Ibrahimova¹ , Murad Abdulla-zada^{1*} 

¹ Azerbaijan State Oil and Industry University, Baku, Azerbaijan

*Corresponding author: e-mail murad.abdullazade@asoil.edu.az

Abstract

Purpose. The Demirli Cu-Mo porphyry system, hosted within Jurassic volcanic-volcaniclastic successions and spatially associated with the Janyatag granitoid pluton (Lesser Caucasus, Azerbaijan), represents a key target for reassessing its residual mineral potential using legacy exploration data and results from renewed exploration initiated in 2024.

Methods. We integrated legacy geological mapping and exploration datasets (1965-1989 and subsequent campaigns) with digitized drilling and sampling archives, 1:1000-scale lithologic-structural mapping covering 1.97 km², systematic sampling of alteration zones and mine-related materials, reverse-circulation drilling conducted in 2024, and 3D geological modeling using Leapfrog Geo and Micromine. Historical geophysical and geochemical datasets, including magnetic surveys, electrical methods such as induced polarization, and lithochemical data, were used to constrain the subsurface geometry of the mineralized system.

Findings. Mineralization is concentrated within the apical and marginal domains of a multiphase hypabyssal intrusive complex. It is localized along NW-SE- to near-N-S-trending fault corridors linked to the Gylyataq deep fault system. Hydrothermal alteration comprises extensive silicification (secondary quartzites) and quartz-sericite, quartz-kaolinite, and quartz-chlorite assemblages, accompanied by stockwork veinlets and disseminated sulfides. Surface and mine-related samples commonly yield Cu concentrations of approximately 0.1-0.7%, with locally elevated Mo values. Legacy datasets indicate a vertically extensive mineralized interval of approximately 200-300 m and a broad anomaly footprint consistent with porphyry-style veinlet and disseminated mineralization.

Originality. The study provides an integrated reinterpretation linking intrusive evolution, structural reactivation, alteration architecture, and 3D geological modeling, thereby refining the exploration model for the Demirli Cu-Mo porphyry system.

Practical implications. The results support step-out drilling along the principal fault corridors and within apical intrusive and alteration domains, and identify alteration patterns that can serve as exploration vectors in resource-definition programs.

Keywords: *porphyry Cu-Mo; Lesser Caucasus; Lok-Karabakh zone; hypabyssal pluton; induced polarization; hydrothermal alteration; stockwork; 3D geological modeling*

1. Introduction

Porphyry copper-molybdenum (Cu-Mo) deposits are the world's principal source of copper and an important source of molybdenum. Their large tonnage, relatively consistent grades, long mine lives, and suitability for bulk extraction make them among the most economically significant mineral systems worldwide [1]-[4]. Their strategic importance has increased with the transition to low-carbon energy systems, which has accelerated demand for copper in renewable-energy technologies, electric transportation, power-transmission networks, and energy-storage infrastructure. Molybdenum is likewise essential for producing high-strength, corrosion-resistant steels used in energy, construction, aerospace, and other advanced industries [1], [4].

As near-surface mineral resources become increasingly depleted, exploration is shifting toward concealed, deeply buried, and structurally complex porphyry systems. Identifying these systems requires a detailed understanding of the

processes that control magma generation and emplacement, volatile exsolution, hydrothermal fluid circulation, wall-rock alteration, structural permeability, and ore deposition. Consequently, modern porphyry research increasingly adopts a mineral-systems approach that integrates structural geology, petrology, geochemistry, geophysics, drilling data, and three-dimensional geological modeling [5]-[7].

Porphyry deposits are now widely interpreted as components of long-lived magmatic-hydrothermal systems rather than as isolated mineralized intrusions. They commonly form in convergent-margin settings, where hydrous, oxidized magmas undergo differentiation, repeated recharge, shallow-crustal emplacement, and volatile saturation. Ore formation may involve multiple intrusive and hydrothermal pulses, with successive events modifying the distribution of permeability, alteration, and mineralization. The resulting deposit geometry therefore reflects the combined influence of magmatic evolution, structural architecture, host-rock properties, and the efficiency of fluid and metal transport [3], [4], [7], [8].

Received: 13 April 2026. Accepted: 15 September 2026. Available online: 26 September 2026

© 2026. N. Pashayev, S. Ibrahimova, M. Abdulla-zada

Mining of Mineral Deposits. ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)

This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted reuse, distribution, and reproduction in any medium, provided the original work is properly cited.

Structural controls are especially important in shaping the spatial organization of porphyry systems. Regional faults may facilitate magma ascent from deeper crustal levels, whereas subsidiary faults, fractures, intrusive contacts, and structural intersections focus hydrothermal fluid flow at the deposit scale. Repeated fault reactivation can generate transient permeability and promote multiple stages of veining, alteration, and sulfide deposition. Structural analysis is therefore essential for reconstructing the evolution of porphyry systems and for predicting the location of concealed mineralized zones [6], [7], [9].

Hydrothermal alteration provides another key record of system evolution. Classical porphyry models distinguish potassic, phyllic, argillic, and propylitic alteration zones, but natural systems rarely preserve idealized concentric patterns. Alteration assemblages are commonly displaced, truncated, or superimposed due to repeated intrusive emplacement, shifting fluid pathways, structural reactivation, erosion, and lithologic heterogeneity. Distinguishing individual alteration stages and their cross-cutting relationships is therefore necessary to establish the temporal sequence of hydrothermal processes and to evaluate their relationship to economically significant mineralization [4], [5], [7], [10].

Recent advances in digital geological modeling have substantially improved the study of such complex systems. Three-dimensional models allow lithologic boundaries, intrusive bodies, fault networks, alteration domains, and mineralized zones to be reconstructed within a consistent spatial framework. In contrast to conventional maps and cross-sections, which provide discontinuous two-dimensional representations, modern modeling platforms can integrate field observations, drill-hole data, geophysical results, historical exploration records, and interpretive constraints simultaneously [5], [7].

Implicit modeling is particularly valuable when geological datasets are heterogeneous or incomplete. Geological surfaces can be interpolated from contact points, structural measurements, drill-hole intersections, and interpretive rules, enabling rapid evaluation of alternative geological scenarios. These models are not merely visualization products; they provide analytical frameworks for testing geological relationships, assessing structural controls, identifying data gaps, evaluating uncertainty, and refining exploration targets [5], [9].

These methods are particularly relevant to mature mining districts. Many long-explored deposits contain extensive legacy datasets from multiple exploration campaigns, often collected using different coordinate systems, logging standards, analytical methods, and interpretive concepts. Although these datasets may contain valuable information, they are commonly fragmented across maps, reports, drill logs, cross-sections, and geophysical archives. Reprocessing and integrating them with modern geological concepts can substantially improve understanding of deposit architecture and ore-forming evolution without relying exclusively on new drilling [5], [7].

The Lesser Caucasus is a major metallogenic province within the Alpine-Himalayan orogenic belt. It hosts numerous porphyry, epithermal, skarn, and volcanogenic massive-sulfide deposits, formed during a complex geodynamic history that spans Neotethyan subduction, island-arc development, continental collision, post-collisional deformation, and repeated magmatic activity from the Mesozoic to the Cenozoic [11]–[14].

The regional tectonic evolution was controlled by convergence among the Eurasian margin, the South Armenian

Block, and adjacent microcontinental terranes during the closure of the Neotethys Ocean. This process produced long-lived calc-alkaline magmatism and widespread emplacement of intermediate- to felsic intrusive complexes. Hydrous magmas, commonly represented by diorite, quartz diorite, granodiorite, and quartz monzonite, were emplaced during successive tectono-magmatic episodes. Their differentiation and repeated replenishment created favorable conditions for volatile exsolution, prolonged hydrothermal circulation, and the formation of porphyry Cu-Mo systems across Armenia, Azerbaijan, Georgia, northeastern Türkiye, and northwestern Iran [11], [12], [15], [16].

Regional and deposit-scale structures strongly controlled the distribution of magmatism and mineralization throughout the Lesser Caucasus. Deep-seated faults served as long-lived pathways for magma ascent, whereas secondary fracture networks and intersections of faults with intrusions controlled fluid circulation and ore localization. The close spatial association among intrusive complexes, major faults, hydrothermal alteration, and mineralization indicates that structural architecture was a fundamental component of regional metallogenic development [12], [14], [17].

Within the Lesser Caucasus, the Lok-Karabakh metallogenic belt is particularly prospective for porphyry copper mineralization. It comprises Upper Jurassic to Cretaceous volcanic and volcano-sedimentary sequences intruded by Late Cretaceous to Paleogene calc-alkaline plutonic and subvolcanic rocks. Porphyry Cu-Mo deposits within the belt are spatially and genetically associated with this long-lived arc magmatism and commonly show evidence of multiphase intrusive activity, extensive hydrothermal alteration, and structurally controlled mineralization [14]–[18].

The Demirli Cu-Mo deposit lies within the Lok-Karabakh belt and is a mature porphyry system that has been investigated over several generations of geological exploration. Previous work established the principal features of its lithology, intrusive composition, hydrothermal alteration, mineralization, and economic potential. However, most studies examined these components separately or focused primarily on ore delineation and reserve estimation. Consequently, the spatial relationships among intrusive phases, faults, alteration zones, and mineralized bodies have not been fully reconstructed within a single three-dimensional geological framework.

This limitation is particularly important because the geometry of a multiphase porphyry system cannot be adequately interpreted from isolated maps, drill sections, or individual datasets. Intrusive contacts may change orientation with depth, fault zones may offset or channel mineralization, and alteration assemblages may overlap due to successive hydrothermal events. Without integrated spatial analysis, these relationships can remain ambiguous, leading to oversimplified interpretations of deposit evolution.

The present study is based on the hypothesis that integrating historical exploration data with recent geological observations and three-dimensional modeling can yield a more reliable reconstruction of the Demirli porphyry system. The approach combines geological mapping, drill-hole records, structural observations, petrographic data, hydrothermal alteration data, geophysical results, and archival exploration materials within a unified digital environment. This integration is used to define the geometry of the main lithologic and intrusive units, characterize the structural framework, ex-

mine the distribution of alteration and mineralization, and evaluate their spatial relationships.

The study's scientific novelty lies in the first comprehensive three-dimensional reinterpretation of the Demirli deposit, based on a combined analysis of legacy and newly acquired geological data. Unlike earlier investigations focused on individual components of the deposit, the present work reconstructs its lithologic, structural, hydrothermal, and metallogenic architecture as an integrated system. The resulting model provides an updated interpretation of the controls on mineralization and demonstrates the value of modern digital modeling for reassessing mature porphyry deposits with heterogeneous historical databases.

The methodological significance of the study extends beyond Demirli. Many established porphyry districts worldwide contain large volumes of underused exploration data accumulated over decades. The workflow presented here demonstrates how such datasets can be standardized, critically evaluated, and integrated into a modern geological model. This approach may support renewed exploration, improve targeting of concealed mineralization, and reduce geological uncertainty in other mature mineral districts.

This study aims to develop an integrated three-dimensional geological model of the Demirli porphyry Cu-Mo deposit and to clarify the geological controls on mineralization by integrating historical exploration records with recent geological, structural, alteration, drilling, and geophysical data.

The following objectives were addressed:

1. To characterize the regional geological and metallogenic setting of the Demirli deposit within the Lok-Karabakh belt.
2. To compile, standardize, and integrate historical and newly acquired geological, drilling, structural, and geophysical data into a unified database.
3. To determine the relationships among intrusive evolution, fault architecture, hydrothermal alteration, and Cu-Mo mineralization.
4. To construct a three-dimensional geological model of the principal lithologic units, intrusive bodies, structural elements, alteration domains, and mineralized zones.
5. To develop an updated geological interpretation to support further exploration and resource assessment at Demirli and in comparable porphyry systems of the Lesser Caucasus.

2. Study area

2.1. Regional geological framework

The Demirli porphyry Cu-Mo deposit lies within the Lok-Karabakh island-arc zone of the Lesser Caucasus, a principal metallogenic province of the Alpine-Himalayan orogenic belt (Fig. 1). This region has undergone a long, complex tectono-magmatic evolution tied to the progressive closure of the Neotethys Ocean and the subsequent convergence between the Eurasian continental margin and adjacent microcontinental terranes. As a result of these geodynamic processes, the Lesser Caucasus hosts numerous economically significant porphyry, epithermal, skarn, and volcanogenic massive sulfide deposits, making it one of the world's most prospective Cu-Mo metallogenic provinces.

The geological architecture of the region developed through repeated episodes of calc-alkaline magmatism, crustal deformation, and hydrothermal activity from the Jurassic to the Cenozoic. Volcanic and plutonic rocks emplaced during successive tectono-magmatic stages constitute the primary host lithologies for porphyry mineralization.

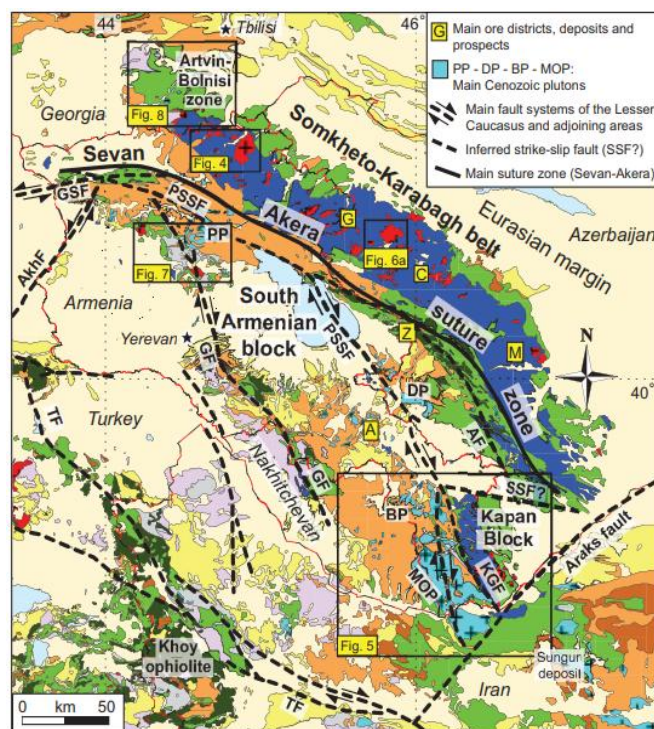


Figure 1. Regional tectonic and metallogenic framework of the Lesser Caucasus, showing the location of the Demirli Cu-Mo porphyry system within the Lok-Karabakh zone [14]

Their emplacement coincided with regional shortening, fault reactivation, and the formation of extensive fracture systems that controlled magma ascent, the emplacement of shallow intrusive bodies, and the subsequent circulation of ore-forming fluids.

Within the Lok-Karabakh belt, porphyry Cu-Mo mineralization is closely associated with intermediate- to felsic calc-alkaline intrusions emplaced into Jurassic volcanic and volcano-sedimentary sequences. Numerous deposits show evidence of multiphase intrusive activity, prolonged hydrothermal alteration, and repeated sulfide mineralization, indicating long-lived magmatic-hydrothermal evolution rather than single intrusive or mineralizing events.

Regional structures exerted first-order control over the localization of mineralization. Deep-crustal fault zones provided pathways for ascending magmas, whereas subsidiary faults and fracture systems controlled the migration of hydrothermal fluids and the distribution of alteration and ore zones. The close spatial relationship between intrusive centers and major structural corridors throughout the Lesser Caucasus demonstrates the fundamental role of tectonic inheritance in concentrating porphyry mineralization.

The Demirli exploration area covers approximately 3 km² in the northeastern part of the Lok-Karabakh belt (UTM Zone 38T; WGS-84). It lies 1-3 km south of Demirli village, and about 10 km southeast of Agdara (Fig. 2). The terrain is rugged, mountainous, and interrupted by narrow valleys and locally developed low-relief areas. Bedrock exposure is discontinuous due to Quaternary deposits, which locally obscure hydrothermal alteration and mineralized zones. Consequently, geological mapping alone is insufficient for reliable subsurface interpretation, underscoring the need to integrate drilling and geophysical datasets.

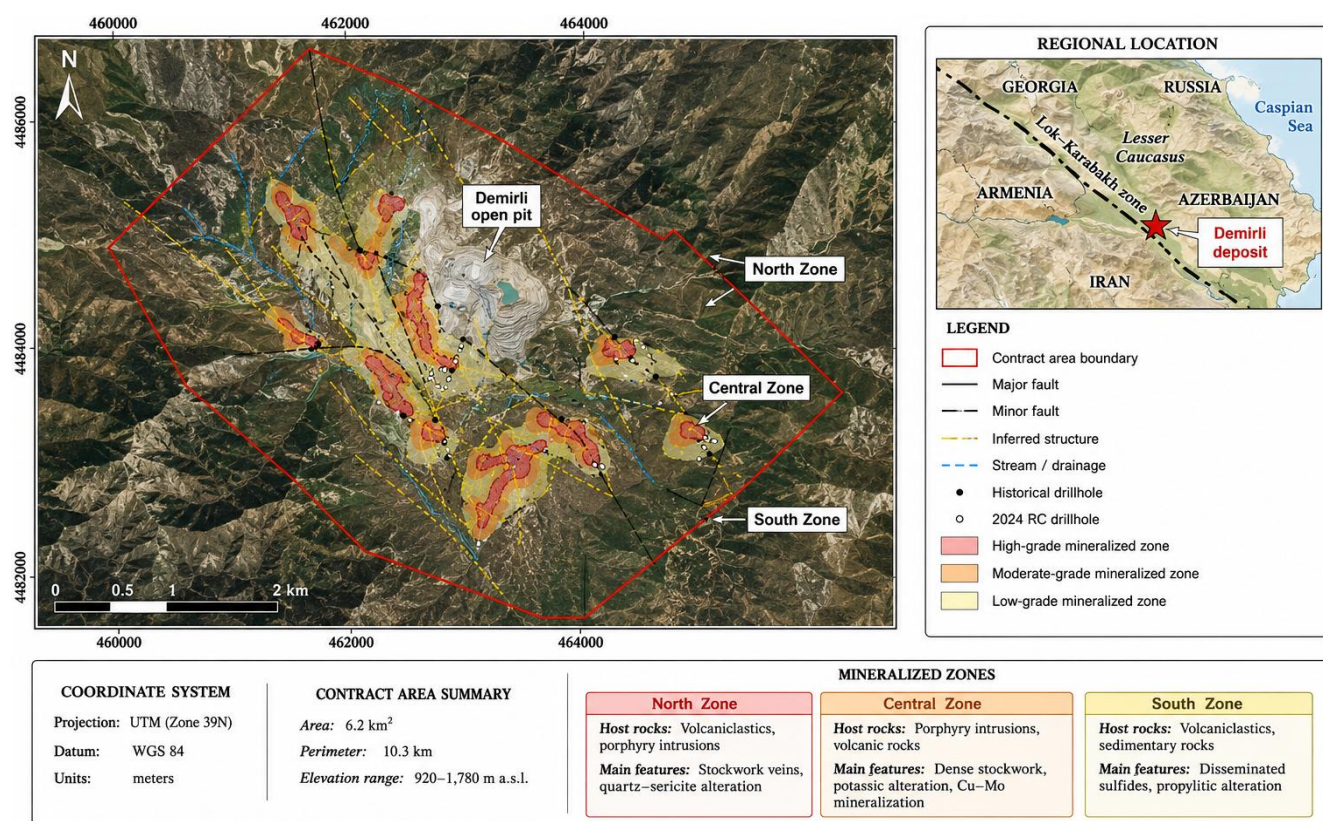


Figure 2. Local geological setting of the Demirli deposit, showing the contract area boundaries, major structures, and the distribution of mineralized zones

The regional stratigraphic succession consists predominantly of Middle to Upper Jurassic volcanic and volcanoclastic rocks, including andesitic, dacitic, and pyroclastic facies, locally overlain by Lower Cretaceous carbonate sequences. These rocks are intruded by numerous hypabyssal intrusions genetically related to the Janyatag granitoid complex. Throughout the district, the spatial distribution of ore occurrences reflects the combined influence of lithologic composition, magmatic intrusions, and regional structural architecture. Particularly favorable conditions for porphyry mineralization occur in the northeastern part of the Demirli district, where extensive hydrothermal quartzites developed around the apical portions of the Janyatag intrusive complex.

The regional geological setting is therefore typical of a convergent-margin magmatic arc, where long-lived tectonic activity, repeated calc-alkaline magmatism, and prolonged hydrothermal circulation collectively controlled the development of porphyry Cu–Mo mineralization. This tectono-magmatic framework provides the geological context needed to understand the origin and present-day architecture of the Demirli deposit.

2.2. Deposit geology

The Demirli Cu–Mo deposit is hosted primarily in Middle-Upper Jurassic volcanic and volcanogenic rocks, which form the principal lithologic framework of the ore-bearing system (Fig. 3). These rocks are locally overlain by Lower Cretaceous carbonate deposits and are intermittently covered by Quaternary sediments. According to previous geological investigations, the Bathonian volcanic succession is the primary ore-hosting interval and contains most of the economically significant Cu–Mo mineralization.

The volcanic succession comprises tuffaceous sandstones, volcanoclastic conglomerates, crystal and lithic tuffs, andesitic to andesitic-basaltic lava flows, and their pyroclastic equivalents. These rocks show pronounced lateral and vertical facies variations, reflecting shifts in depositional environments and volcanic activity during arc development. Hydrothermal alteration has extensively modified the primary volcanic succession, producing widespread secondary quartzites and metasomatic rocks in the central part of the deposit.

Field observations indicate considerable lithologic variability throughout the deposit. In the northwestern sector, the volcanic sequence comprises alternating beds of tuffaceous sandstones, coarse-fragmental tuffs, volcanic breccias, and andesitic tuff lava flows. In the southern part of the deposit, volcanic rocks form two major volcano-sedimentary packages dominated by agglomeratic tuffs, porphyritic andesite-basalt lava flows, and interbedded pyroclastic deposits. These variations reflect repeated volcanic eruptions accompanied by rapid shifts in eruptive style and depositional conditions.

The Demirli deposit is spatially and genetically associated with the Janyatag intrusive complex, the district's principal magmatic center (Fig. 4). This hypabyssal plutonic complex covers approximately 65 km² and is among the largest intrusive bodies exposed in the northeastern Lesser Caucasus. It consists predominantly of diorite, quartz diorite, granodiorite, granosyenite, syenite-diorite, granite, and subordinate aplite, with porphyritic varieties occurring mainly in the apical and marginal parts of the intrusion.

Geologic mapping indicates that the intrusive complex was emplaced during at least two principal magmatic stages. Earlier intermediate intrusions, dominated by diorite, quartz diorite, and syenite-diorite, form the central part of the pluton.

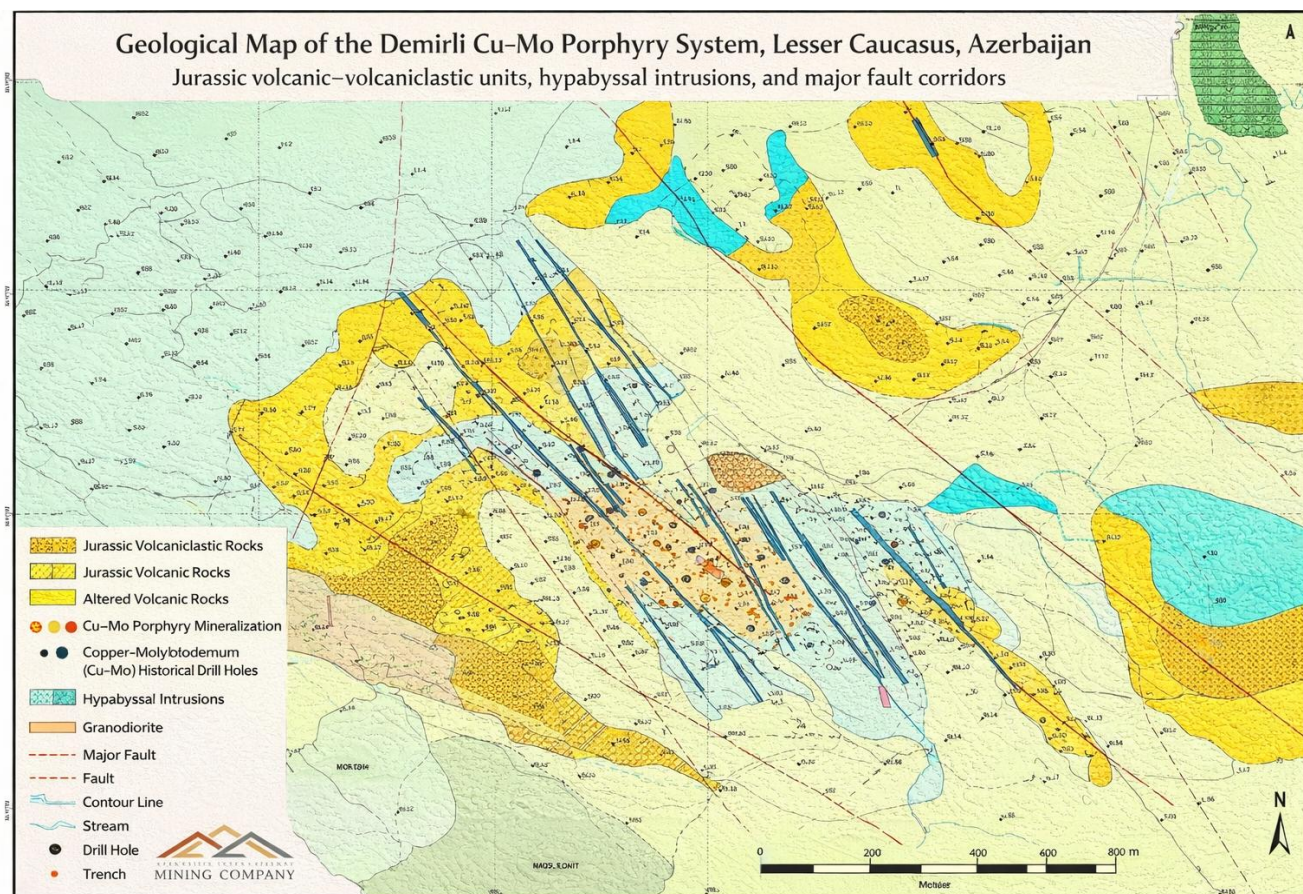


Figure 3. Geological map of the Demirli Cu-Mo porphyry system showing Jurassic volcanic-volcaniclastic units, hypabyssal intrusions, and major fault corridors

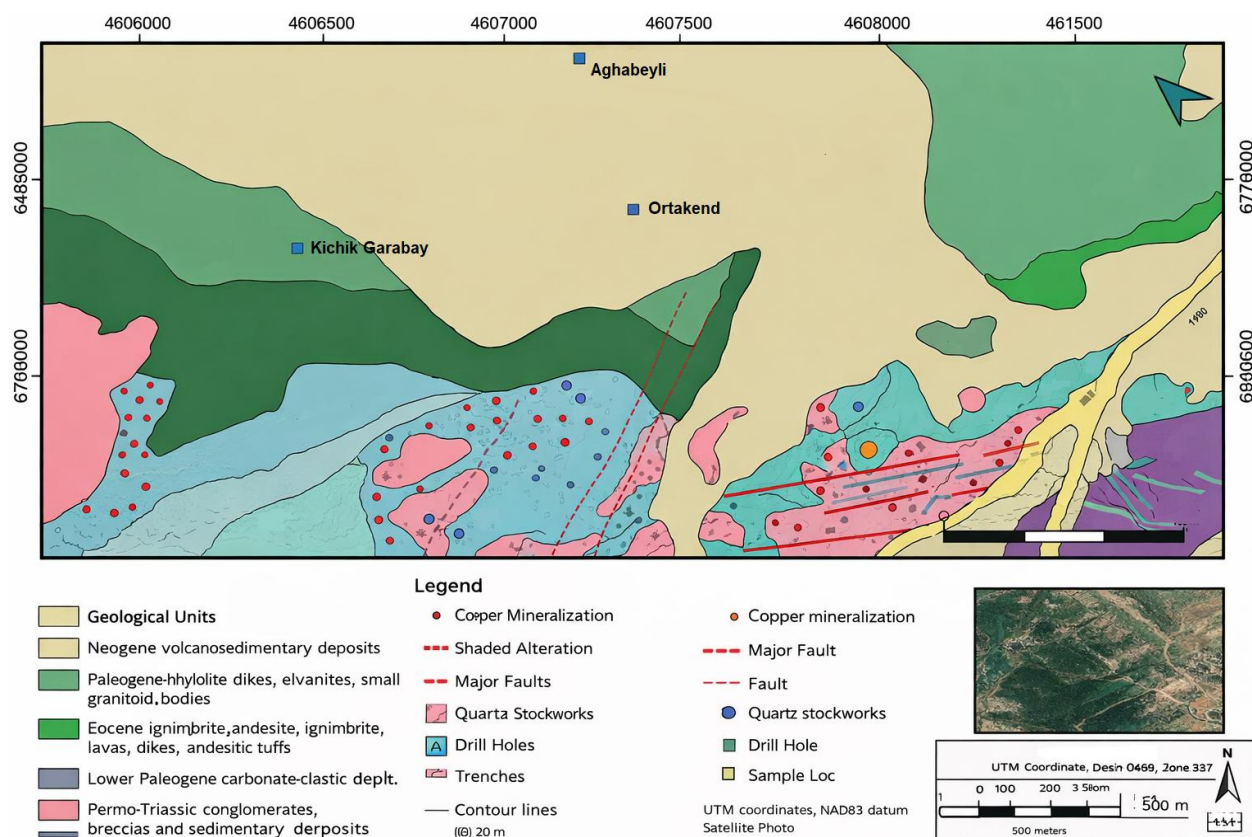


Figure 4. Lithologic-structural map highlighting intrusive phases of the Janyatag hypabyssal pluton and their spatial relationship to mineralization

In contrast, younger felsic phases, including granites and granite porphyries, occur mainly along its margins and apical zones. Numerous dykes and small intrusive bodies of diorite porphyrite, quartz diorite porphyrite, syenite-diorite porphyrite, aplite, pegmatite-aplite, dacite, and andesite-dacite composition intrude both the volcanic succession and earlier intrusive phases. The abundance of these bodies indicates prolonged magmatic activity and repeated intrusion-related fracturing, which significantly increased crustal permeability.

Hydrothermal alteration is particularly intense around the apical portions of the intrusive complex, where volcanic and intrusive rocks have been transformed into extensive metasomatic assemblages and secondary quartzites (Fig. 5). The principal alteration types include monomineralic quartzites, quartz-sericite, quartz-chlorite, and quartz-kaolinite assemblages, with quartz-sericite alteration the dominant metasomatic facies throughout the deposit. In many outcrops, altera-

tion zones are accompanied by pervasive silicification, pyritization, kaolinization, limonitization, and local hydrothermal brecciation, indicating repeated interaction between host rocks and ascending hydrothermal fluids.

Ore mineralization is typical of porphyry Cu-Mo systems and occurs predominantly as disseminated sulfides and quartz-sulfide stockworks developed within altered volcanic rocks and porphyritic intrusions. Chalcopyrite is the principal copper-bearing mineral, whereas molybdenite occurs mainly in quartz veinlets and fracture-controlled mineralized zones. Sulfide mineralization is concentrated around the apical parts of the intrusive complex and along zones of enhanced fracturing, underscoring the combined influence of intrusive emplacement and structural permeability on ore localization. Available exploration data indicate that copper grades commonly range from 0.1 to 0.7 wt.%, whereas molybdenum occurs as localized but economically significant enrichments that require further mineralogical characterization.

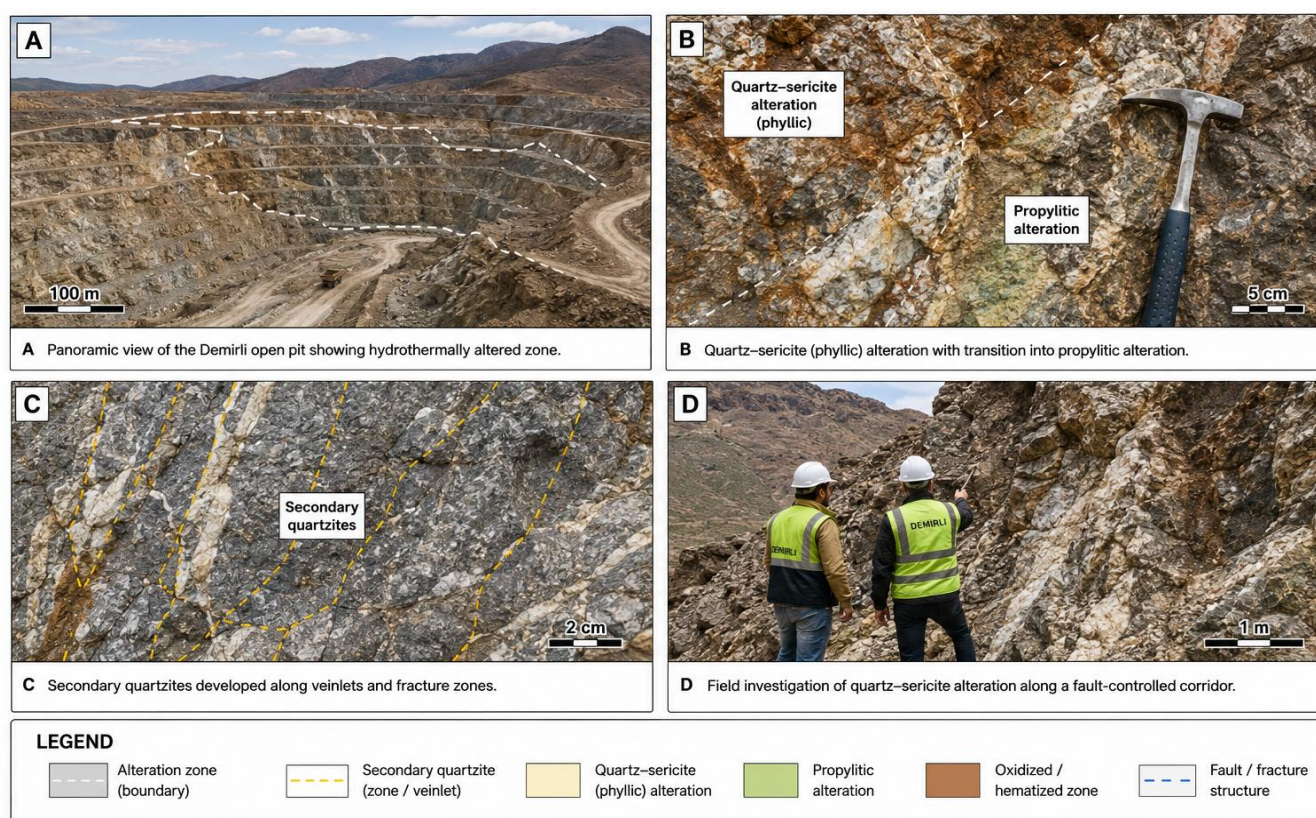


Figure 5. Representative field photographs of hydrothermal alteration at Demirli, including secondary quartzites and quartz-sericite metasomatites

Overall, the geological characteristics of the Demirli deposit indicate a close genetic relationship among Jurassic volcanic host rocks, multiphase calc-alkaline intrusions, hydrothermal alteration, and structurally controlled Cu-Mo mineralization. This combination of geological features is characteristic of mature porphyry systems and provides the geological foundation for the three-dimensional modeling and structural interpretation presented in this study.

2.3. Hydrothermal alteration and ore mineralization

Hydrothermal alteration at the Demirli deposit records the evolution of a long-lived magmatic-hydrothermal system genetically linked to the emplacement of the Janyatag intrusive complex. Geological mapping, drill-core observations,

and petrographic analyses indicate that alteration affected both the volcanic host rocks and the intrusive bodies, producing extensive metasomatic zones marked by pronounced mineralogical and textural changes. Although the alteration pattern generally resembles that of calc-alkaline porphyry systems, local overprinting and structural control have produced considerable spatial variability.

The central part of the deposit is dominated by quartz-rich metasomatites and secondary quartzites that developed around the apical portions of the intrusive complex. Quartz-sericite alteration is the most widespread alteration facies and is commonly accompanied by pervasive silicification and abundant disseminated pyrite. Quartz-chlorite and quartz-kaolinite assemblages occur locally, whereas zones of limo-

nitization, kaolinization, and hydrothermal brecciation develop mainly within intensely fractured rocks. Together, these alteration assemblages define the core of the hydrothermal system and record repeated interaction between ascending magmatic fluids and the surrounding host rocks.

The structural framework of the deposit strongly controls the distribution of hydrothermal alteration. Major faults, subsidiary fractures, intrusive contacts, and dense fracture networks provide the principal pathways for hydrothermal fluid migration. As a result, alteration zones commonly exhibit irregular geometries and locally overlap due to repeated fluid circulation and successive hydrothermal events, rather than forming idealized concentric patterns. Similar structural control is widely recognized in mature porphyry Cu-Mo systems worldwide.

Copper-molybdenum mineralization occurs predominantly as disseminated sulfides and quartz-sulfide stockworks hosted in altered volcanic rocks and porphyritic intrusions. Chalcopyrite is the principal copper-bearing mineral, whereas molybdenite is mainly confined to quartz veinlets and fracture-controlled mineralized zones. Pyrite is ubiquitous throughout the hydrothermal system and commonly accompanies both copper and molybdenum mineralization. Locally, bornite, chalcocite, covellite, and secondary oxidation products occur in response to variations in hydrothermal conditions and subsequent weathering.

Ore bodies cluster around the apical portions of the intrusive complex and within highly fractured zones, indicating a strong spatial relationship among intrusive emplacement, structural permeability, and sulfide deposition. Available exploration data indicate that copper grades generally range from approximately 0.1 to 0.7 wt.%, whereas molybdenum is more irregularly distributed, with locally economically significant concentrations. These observations confirm the classification of Demirli as a typical porphyry Cu-Mo system characterized by stockwork mineralization and structurally controlled ore distribution.

The close spatial association among intrusive rocks, hydrothermal alteration, and sulfide mineralization demonstrates that these components form an integrated geological system. Their geometry and relationships provide the basis for reconstructing the deposit's three-dimensional architecture and for the geological modeling presented in the following sections.

3. Materials and methods

The methodological workflow combined historical exploration records with geological, drilling, sampling, mineralogical, and digital modeling data collected during the renewed exploration program at the Demirli Cu-Mo deposit in 2024. The principal objective of the workflow was to standardize heterogeneous legacy data, integrate it with newly acquired observations, reconstruct the deposit's three-dimensional geological architecture, and compare the resulting interpretation with the company's December 2024 block-model resource evaluation.

The historical database comprised geological exploration information accumulated during several campaigns from the 1960s onward, including geological maps, trench and drill-hole records, geophysical and geochemical surveys, topographic information, analytical results, and archived geological reports. Earlier exploration included surface workings, drilling, surface and borehole geophysical investigations,

topographic-geodetic surveys, and laboratory studies. Historical geological mapping of the broader district was conducted primarily at scales of 1:50000 and 1:10000, whereas the renewed 2024 program provided higher-resolution, deposit-scale observations.

The 2024 field program included lithologic-structural mapping at a scale of 1:1000 over 1.97 km², reverse-circulation (RC) drilling, documentation of available historical core, sampling of natural exposures and hydrothermally altered rocks, and investigation of mine- and processing-related waste materials. A total of 898 RC drillholes were completed during the 2024 program, with a cumulative drilled length of 8980 m and an average depth of approximately 10 m. Drillhole collar coordinates and downhole inclination data were recorded for spatial integration.

The 2024 drilling and geological observations were combined with historical drilling information, including data from previous Base Metals mine operations, which were digitized by Azerbaijan International Mining Company Limited (AİMKL). The December 2024 mineral-resource evaluation, therefore, represents an integrated dataset that combines the newly acquired RC drilling with the digitized historical mine and exploration database.

Archival geological information was converted to a digital format before interpretation. The digitization workflow included drillhole records, geological maps and sections, lithologic information, topographic data, and available analytical records. Historical drillhole information was reconciled with collar locations, geological logs, and archived documentation, where possible, before incorporation into the integrated database.

Lithologic descriptions and geological terminology from different exploration periods were standardized to enable comparison between legacy and 2024 datasets. Drillhole coordinates, inclination data, lithologic observations, alteration characteristics, structural data, and available assay data were then organized within a common spatial framework. Geological sections and three-dimensional representations were prepared from the standardized dataset using Leapfrog Geo and Micromine. The project documentation records the digitization of historical data and the preparation of geological sections and block models as part of the renewed exploration program.

Particular attention was given to incomplete historical information. Because the available project documentation does not describe a numerical procedure for replacing or interpolating missing historical assays, no synthetic assay values were assigned to intervals lacking analytical information. These missing analytical intervals were treated as missing data rather than as zero-grade samples. Geological information from historical drillholes could nevertheless be retained for interpretation when lithological contacts or structural relationships were considered sufficiently documented. In this way, geological information was separated from analytical grade control, and unsupported grade values were not introduced into the integrated dataset.

This treatment is particularly relevant to the Demirli database because part of the original geochemical and analytical documentation from historical exploration campaigns is incomplete. The project report notes that some primary materials and geochemical analytical results from earlier investigations were lost.

The geological dataset included RC drill cuttings, available historical drill core, surface rock samples from natural exposures and hydrothermally altered zones, and representative mine- and processing-related materials. Surface investigations focused on the principal lithologic units, secondary quartzite and metasomatic zones, structurally controlled alteration corridors, and visibly mineralized exposures.

Representative surface samples were also selected for mineralogical characterization by X-ray diffraction (XRD). For the documented XRD investigation, samples D2, D3, and ST01 collected from the Demirli deposit were crushed and then ground at the AİMKL chemical laboratory to a particle size of $< 75 \mu\text{m}$. Approximately 15 mg of the prepared powder was introduced into the sample cell for each analysis.

XRD measurements were performed on an OLYMPUS BTX™ III Benchtop XRD analyzer equipped with a Co X-ray tube. The powder was mixed in the sample holder using the instrument's external shaking system, and the analytical run terminated automatically after 200 measurements. Mineral phases were identified using MDI JADE 8.8 software and the PDF-4 Minerals 2023 database from the International Center for Diffraction Data (ICDD). The project report also notes that using a Co tube may introduce uncertainty in identifying certain Cu-bearing mineral phases; therefore, the XRD results were interpreted primarily in conjunction with petrographic and geological observations.

Petrographic observations were used to complement the XRD results and to distinguish alteration assemblages that cannot be reliably resolved by bulk mineral identification alone. Particular attention was given to quartz-sericite, quartz-kaolinite, and chlorite-bearing assemblages, as well as to their spatial relationships with stockwork and disseminated sulfide mineralization.

Chemical Cu and Mo values used in the integrated geological and resource database were derived from historical analytical records and the 2024 exploration dataset. However, the project documentation for this study does not specify the instrumental Cu-Mo assay method, analytical detection limits, or the insertion frequencies of certified reference materials, blanks, and analytical duplicates. These parameters are therefore not reconstructed here. This limitation applies to the analytical metadata rather than to the documented XRD mineralogical procedure described above.

Operational grade control during mine planning is described separately in the project documentation. Grade-control sampling uses 5-m blast-hole sampling. Material is then classified into grade groups and used by mine geologists for ore selection and grade-control mapping, in coordination with metallurgical and laboratory personnel. Because this operational procedure is not equivalent to laboratory assay QA/QC based on certified standards, blanks, and duplicates, it was not treated as a substitute for analytical QA/QC in the present study.

The three-dimensional interpretation incorporated surface mapping, drillhole geology, lithologic contacts, intrusive bodies, hydrothermal alteration, structural observations, topography, and available analytical data. Historical geophysical and geochemical results were used as supporting constraints when they could be spatially related to the geological framework.

Historical geophysical information included surface electrical methods, induced-polarization observations, magnetic investigations, and borehole geophysical data. These datasets

were used to evaluate the continuity of geological and alteration domains and to assist interpretation in areas with limited bedrock exposure or drilling control. The methodology did not rely on repeated re-description of individual TDIP acquisition parameters; rather, the geophysical results were treated as complementary constraints on the geometry of altered, intrusive, and structurally controlled domains.

Three-dimensional geological modeling was performed in Leapfrog Geo and Micromine. The modeling workflow integrated surface geology, drillhole data, topography, lithologic boundaries, intrusive contacts, alteration domains, and structural interpretations. Leapfrog Geo was used to visualize drillhole distribution and the principal geological relationships, whereas Micromine was used to generate geological sections and to represent Cu mineralization within the block-model environment. The company's project documentation includes both Leapfrog-based drillhole models and Micromine block-model sections of the western part of the deposit.

The modeling procedure was iterative. Geological contacts interpreted from surface mapping were compared with drillhole intersections and existing geological sections, and the geometries of the main volcanic-volcaniclastic units, intrusive bodies, hydrothermally altered rocks, and structural corridors were then refined. Faults and intrusive contacts were incorporated as geological controls where supported by mapping, drilling, or geophysical evidence. Particular emphasis was placed on the apical and marginal parts of the Janyatag intrusive complex and on NW-SE to near N-S structural corridors, because these domains coincide with the most intense alteration and stockwork mineralization.

The resulting 3D geological model was used primarily to reconstruct the spatial relationships among lithology, intrusive architecture, structures, hydrothermal alteration, and mineralization. It also provided the geological framework against which the existing company block-model resource evaluation was assessed.

Physical-property data were used to delineate the principal weathering and geological domains. The project report provides the following bulk-density assignments for the main modeled material types:

- alluvial material: 1.9 t/m^3 ;
- oxide material: 2.3 t/m^3 ;
- supergene material: 2.3 t/m^3 ;
- hypogene material: 2.6 t/m^3 ;
- dyke material: 2.6 t/m^3 .

These density values are consistent with additional physical-property data reported for the principal rock groups, with specific-gravity ranges of approximately $2.60\text{--}2.65 \text{ g/cm}^3$ for volcanic-sedimentary rocks, $2.63\text{--}2.69 \text{ g/cm}^3$ for intrusive rocks, $2.54\text{--}2.68 \text{ g/cm}^3$ for subvolcanic facies, and $2.48\text{--}3.25 \text{ g/cm}^3$ for contact-metasomatic and hydrothermally altered rocks.

The mineral-resource figures discussed in this study were not independently recalculated by the authors from raw assay data. Instead, they were taken from the AİMKL December 2024 block-model evaluation, which integrates 2024 RC drilling data with historical Base Metals data digitized by AİMKL. This distinction is important because the available project documentation provides the resulting block-model classification, density assignments, and economic cut-off basis, but does not report all underlying geostatistical estimation parameters.

A 0.20% Cu cut-off grade was used for the reported December 2024 mineral-resource inventory. According to the project documentation, the selected threshold incorporates current operating costs and metal price assumptions and was applied to a conceptual open-pit operation. The technical-economic evaluation identifies open-pit extraction as the preferred mining method for the deposit.

Open-pit economic evaluation was also undertaken under a copper-price scenario of approximately US\$ 9000/t Cu. At this price assumption, the optimization demonstrated a mineable shell encompassing part of the global resource above the adopted cut-off, supporting the interpretation that the 0.20% Cu threshold represents a conservative basis for the current resource assessment rather than a purely geological mineralization boundary.

The company block-model documentation available for this study does not specify the parent-block and sub-block dimensions, compositing interval, grade-interpolation algorithm, variogram model, search-ellipsoid dimensions, minimum or maximum number of samples, or number of search passes. Consequently, these parameters were neither reconstructed nor assigned assumed values in the present study. The resource figures are therefore reported as results of the documented December 2024 company evaluation rather than as an independently reproduced geostatistical estimate.

Mineral resource classification in the December 2024 block model followed the principles of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (JORC Code, 2012 edition). Classification was based on geological confidence, the spatial distribution of drilling, and the interpreted continuity of geology and mineralization.

Measured and indicated categories represent the better-constrained parts of the mineralized system. In contrast, Inferred Resources were assigned primarily to peripheral blocks, where drillhole spacing was wider and geological and mineralization continuity were inferred from relationships observed in the more densely investigated central area. Blocks for which geological confidence was insufficient for formal classification were retained as unclassified material in the December 2024 inventory.

At a Cu cut-off of 0.20%, the December 2024 model comprises 5.50 Mt at 0.46% Cu in the Measured category, 9.509 Mt at 0.45% Cu in the Indicated category, 27.780 Mt at 0.37% Cu in the Inferred category, and 15.559 Mt at 0.44% Cu as unclassified material, for a total modeled inventory of 58.348 Mt at an average grade of 0.41% Cu, equivalent to approximately 238.97 kt of contained Cu. All tonnages are reported as dry metric tonnes, and minor numerical differences may result from rounding.

4. Results

The December 2024 block-model evaluation, using a Cu cut-off grade of 0.20%, estimates a total residual mineral resource of 58.35 Mt at an average grade of 0.41% Cu, equivalent to approximately 238.97 kt of contained copper. Stockwork-style sulfide mineralization occurs within altered domains (Fig. 6). The reported mineral resources include 5.50 Mt of Measured Resources grading 0.46% Cu, 9.51 Mt of Indicated Resources grading 0.45% Cu, 27.78 Mt of Inferred Resources grading 0.37% Cu, and 15.56 Mt of unclassified material averaging 0.44% Cu.



Figure 6. *Stockwork-style sulfide veinlets formed within hydrothermally altered host rocks at the Demirli deposit*

These estimates indicate that copper mineralization is distributed throughout a laterally continuous, vertically developed mineralized system and provide a quantitative basis for further resource definition and for step-out drilling programs.

Historical exploration data, together with the 2024 reverse-circulation (RC) drilling program, formed the basis for the integrated geological database used in three-dimensional modeling. The combined drilling dataset provides comprehensive geological control over the central part of the deposit and enables reconstruction of lithologic contacts, intrusive bodies, hydrothermal alteration zones, and mineralized domains (Fig. 7).

Sampling of natural outcrops, mine exposures, and waste materials indicates that copper grades generally range from 0.10% to 0.70% Cu, consistent with historical analytical results and typical of porphyry-style disseminated and stockwork mineralization. Locally elevated molybdenum concentrations occur within intensely altered domains, particularly where quartz-sericite alteration is well developed.

Geologic mapping confirms that hydrothermal alteration is widespread throughout the deposit. Secondary quartzites and quartz-sericite metasomatites occur in both volcanic-volcaniclastic host rocks and along intrusive endo- and exocontacts. Stockwork sulfide veinlets are consistently associated with these altered rocks, forming the characteristic vein-controlled mineralization pattern of the Demirli porphyry system.

Time-domain spectral induced polarization (TDIP) surveys identify extensive chargeability anomalies with polarization indices of approximately 6-8%, significantly exceeding the regional background of approximately 3%. The highest chargeability responses spatially coincide with intrusive contacts and zones of intense quartz-sericite alteration.

Magnetic data delineate arcuate anomaly patterns that align with the geometry of the intrusive complex and the major structural corridors identified through geological mapping and drilling. Integrating magnetic and induced polarization data with geological observations substantially improved delineation of concealed intrusive contacts and structurally controlled mineralized zones. The integrated three-dimensional geological model integrates historical and recent drilling data, detailed geological mapping, topographic information, and geophysical constraints into a unified geological framework. The model illustrates the spatial relationships among intrusive bodies, lithologic units, hydrothermally altered rocks, fault systems, and mineralized domains.

The highest density of stockwork mineralization occurs where apical intrusive domains intersect major NW-SE to nearly N-S fault corridors. Mineralized intervals are documented to depths of approximately 200-300 m, indicating significant vertical continuity of the porphyry system (Fig. 8).

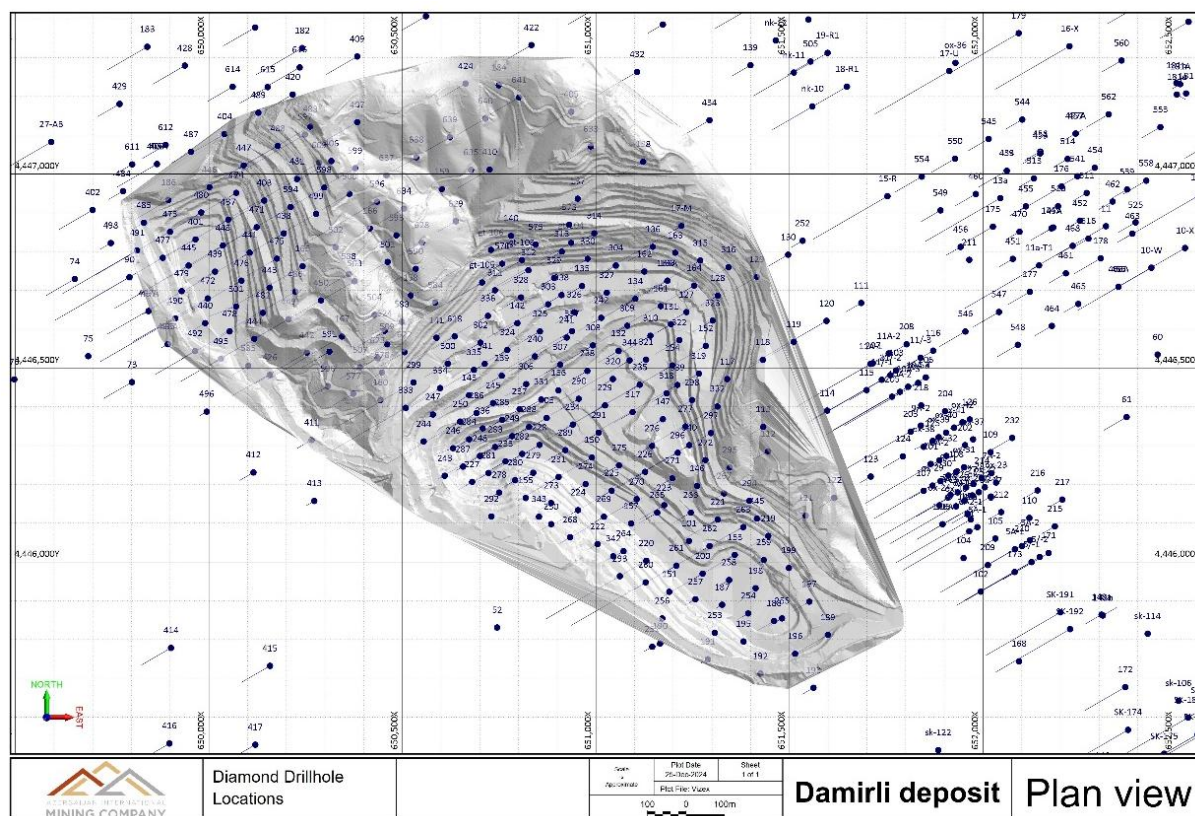


Figure 7. Distribution of historical drillholes and 2024 reverse-circulation drillholes used for database compilation and 3D geological modeling

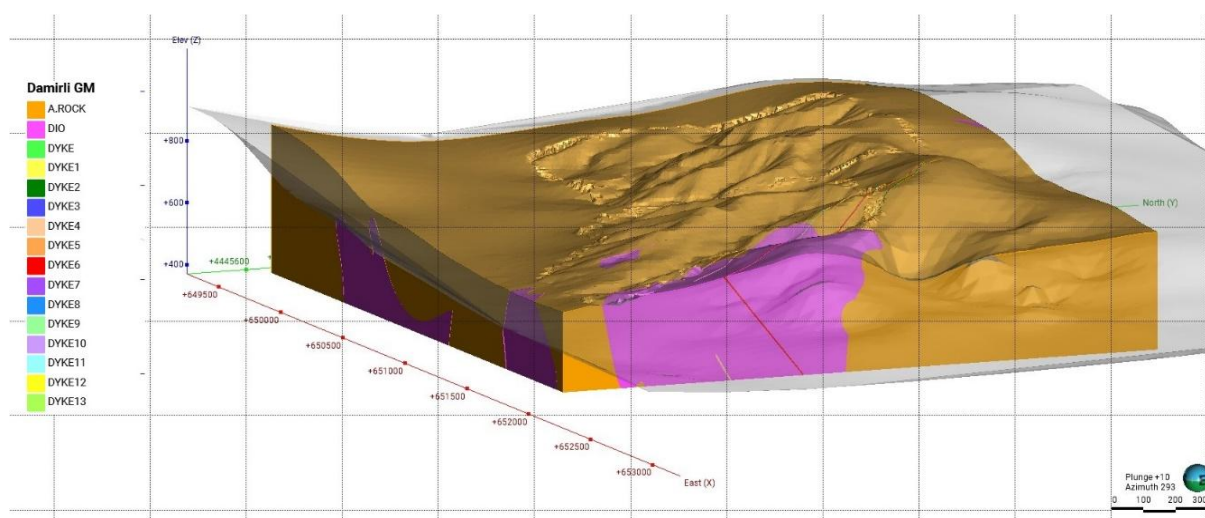


Figure 8. Three-dimensional geological model of the Demirli porphyry system, constructed from integrated drilling, mapping, and geophysical datasets

5. Discussion

The integrated geological interpretation suggests that the Demirli Cu-Mo deposit records a long-lived magmatic-hydrothermal system that evolved through repeated episodes of magma emplacement, structural reactivation, and hydrothermal fluid circulation. The close spatial association of Cu-Mo mineralization with the apical and marginal parts of the Janyatag hypabyssal pluton and with major fault corridors indicates that intrusive architecture and structural permeability were the principal controls on ore localization (Fig. 9). Similar spatial relationships have been reported for numerous porphyry Cu-Mo deposits worldwide, where shallow intrusive cupolas and struc-

turally prepared zones provide favorable pathways for hydrothermal fluid discharge and ore deposition [2], [6], [7].

The reconstructed intrusive architecture is consistent with a multiphase evolution of the Janyatag pluton. Earlier intermediate intrusions likely established the thermal framework of the hydrothermal system and promoted extensive fracturing of the surrounding rocks. In contrast, younger intrusive phases appear more closely associated with hydrothermal alteration and Cu-Mo mineralization. Numerous dykes and small intrusive bodies further indicate repeated magma injections, which may have prolonged the heat supply and maintained favorable conditions for hydrothermal circulation [7], [8], [19], [20].

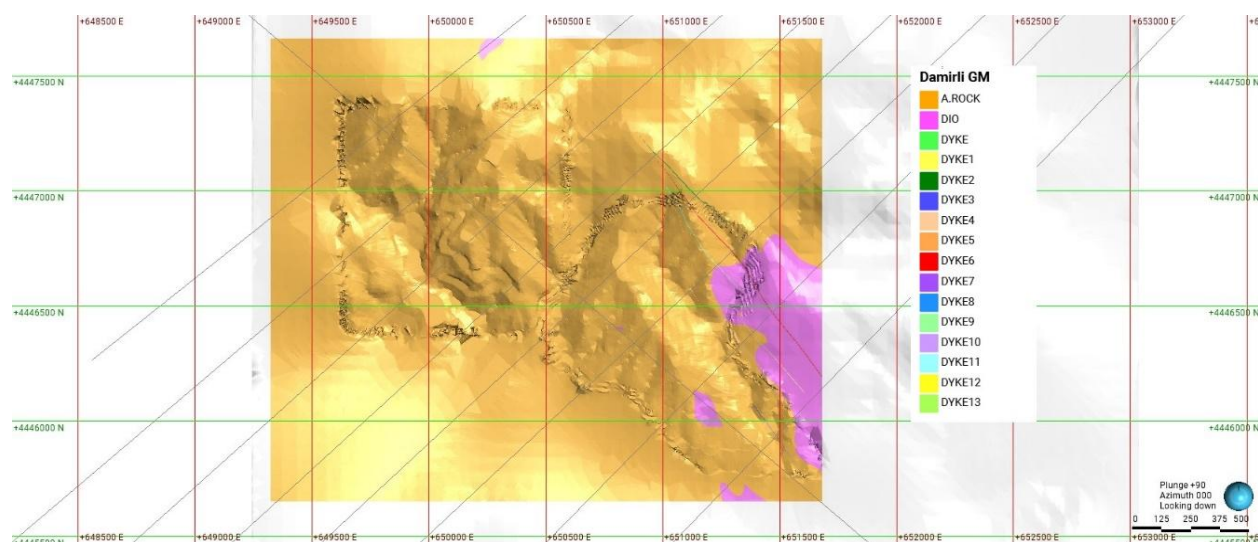


Figure 9. Locations of representative geological cross-sections extracted from the 3D model

Structural interpretation indicates that the Gylyataq deep-fault system served as the principal structural corridor controlling magma ascent and hydrothermal fluid migration. Repeated reactivation of NW-SE- to nearly N-S-trending fault systems appears to have governed both the emplacement of hypabyssal intrusions and the distribution of hydrothermal alteration and sulfide mineralization. In particular, intersections between older NW-trending and younger NE-trending structures coincide with areas of increased fracture density and well-developed stockwork mineralization (Figs. 10 and 11).

Comparable structural relationships have been documented in many porphyry Cu-Mo systems, where long-lived fault corridors remain active through successive magmatic and hydrothermal events [6], [7], [9]. At the Demirli deposit, these structures are spatially associated with the observed vertical continuity of mineralization to depths of approximately 200-300 m and with the lateral extent of hydrothermal alteration surrounding the intrusive complex.

The reconstructed alteration pattern is likewise consistent with a typical porphyry hydrothermal system. Extensive silicification, together with quartz-sericite metasomatism, defines the principal hydrothermal footprint of the deposit. Locally developed quartz-chlorite and quartz-kaolinite as-

semblages occur in more distal or structurally controlled settings and indicate the progressive evolution of hydrothermal conditions. This alteration zonation is widely recognized as an effective exploration criterion in porphyry environments [4], [5], [10], [20]. At the Demirli deposit, the coincidence of quartz-sericite alteration, abundant stockwork veining, and proximity to apical intrusive contacts identifies the most favorable targets for future resource-definition drilling. Additional targeted petrographic and spectral investigations, together with expanded XRD coverage of representative alteration domains, would further improve characterization of alteration mineralogy and enhance exploration targeting.

Geophysical observations provide independent support for the geological interpretation. Time-domain spectral induced polarization surveys delineate chargeability anomalies of approximately 6-8%, substantially exceeding the regional background level of about 3%. These anomalies coincide with intrusive contacts and zones of intense hydrothermal alteration identified from geological mapping and drilling. Magnetic data additionally constrain the geometry of intrusive bodies and major structural corridors, thereby strengthening confidence in the reconstructed three-dimensional geological model.

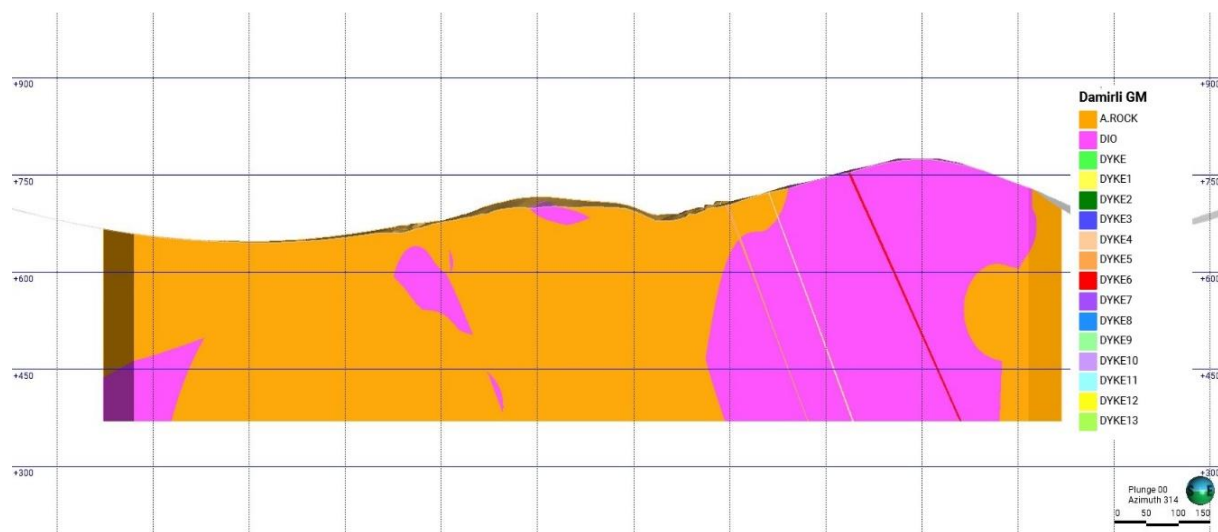


Figure 10. Representative cross-sections extracted from the 3D model (SW-NE orientations) illustrating intrusive geometry and interpreted structural corridors

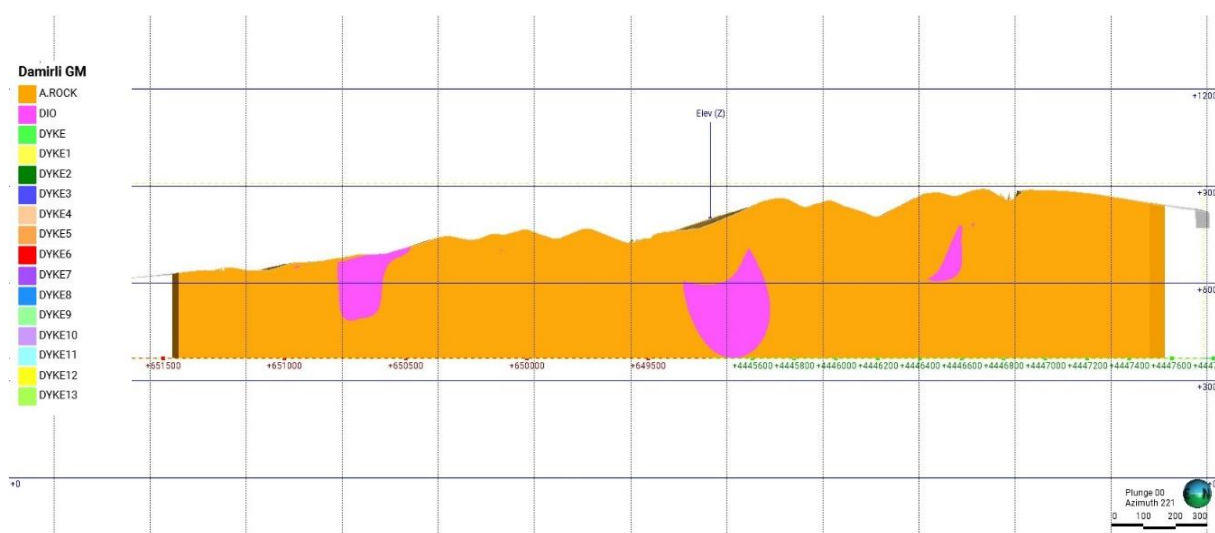


Figure 11. Representative cross-sections extracted from the 3D model (NW-SE orientation), illustrating intrusive geometry and interpreted structural corridors

Integrating geological mapping, drilling, geophysical interpretation, and three-dimensional modeling enables direct visualization of the spatial relationships among lithology, structures, hydrothermal alteration, and mineralization. Rather than treating these datasets independently, their combined interpretation provides a substantially more robust geological framework for exploration planning and resource evaluation.

The December 2024 block-model evaluation indicates that the Demirli deposit retains significant residual mineral resource potential. The reported tonnage and average copper grade fall within the range observed for many porphyry Cu systems, confirming that economically significant mineralization remains within the currently defined mineralized domain. Nevertheless, additional drilling is required to verify mineralization continuity in areas with limited geological control and to improve confidence in future resource estimates.

The results of this study indicate that future exploration should primarily focus on:

- apical and marginal intrusive domains intersected by major fault corridors;
- structural intersection zones with enhanced fracture density;
- concealed targets beneath Quaternary cover where integrated geological and geophysical evidence suggests the hydrothermal system continues.

The integrated three-dimensional geological workflow presented here offers an effective framework for prioritizing exploration targets and refining future mineral resource evaluations.

6. Conclusions

Demirli is confirmed to be a large porphyry Cu-Mo system hosted in Jurassic volcanic-volcanoclastic rocks and genetically linked to the two-phase Janyatag hypabyssal pluton.

Mineralization is structurally controlled by reactivated NW-SE- to near N-S-oriented fault corridors associated with the Gylyataq deep fault system.

Extensive hydrothermal alteration, dominated by secondary quartzites and quartz-sericite assemblages, delineates a large mineralized footprint spanning several square kilometers.

A December 2024 block-model evaluation with a Cu > 0.2% cut-off estimates 58.35 Mt at 0.41% Cu (~239 kt of contained Cu), confirming the presence of a large, vertically

extensive porphyry Cu system and providing a robust quantitative basis for future resource-definition drilling.

Integrated 3D modeling provides a defensible framework for targeting apical intrusive margins, fault intersections, and zones masked by Quaternary cover during future drilling campaigns.

Author contributions

Conceptualization: SI, MA; Data curation: SI, MA; Formal analysis: NP, SI, MA; Funding acquisition: NP, SI, MA; Investigation: SI, MA; Methodology: NP, SI; Project administration: SI, MA; Resources: NP, SI; Software: MA; Supervision: NP, SI; Validation: NP, SI; Visualization: SI, MA; Writing – original draft: SI, MA; Writing – review & editing: NP, MA. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Acknowledgements

The authors would like to express their gratitude to the Azerbaijan International Mining Company for its support related to the publication of this paper.

Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

References

- [1] Sinclair, W.D. (2007). Porphyry deposits. *Mineral Deposits of Canada: A Synthesis of Major Deposit-Types, District Metallogeny, the Evolution of Geological Provinces, and Exploration Methods*, 5, 223-243.
- [2] Cooke, D.R., Hollings, P., & Walshe, J.L. (2005). Giant porphyry deposits: Characteristics, distribution, and tectonic controls. *Economic Geology*, 100(5), 801-818. <https://doi.org/10.2113/gsecongeo.100.5.801>
- [3] Richards, J.P. (2003). Tectono-magmatic precursors for porphyry Cu (Mo-Au) deposit formation. *Economic Geology*, 98(8), 1515-1533. <https://doi.org/10.2113/gsecongeo.98.8.1515>

- [4] Kouzmanov, K., & Pokrovski, G.S. (2012). Hydrothermal controls on metal distribution in porphyry Cu (-Mo-Au) systems. *Geology and Genesis of Major Copper Deposits and Districts of the World: A Tribute to Richard H. Sillitoe*, 16, 573-618. <https://doi.org/10.5382/SP.16.22>
- [5] Cooke, D.R., Wilkinson, J.J., Baker, M., Agnew, P., Phillips, J., Chang, Z., Chen, H., Wilkinson, C.C., Inglis, S., Hollings, P., Zhang, L., Gemmell, J.B., White, N.C., Danyushevsky, L., & Martin, H. (2020). Using mineral chemistry to aid exploration: A case study from the Resolution porphyry Cu-Mo deposit, Arizona. *Economic Geology*, 115(4), 813-840. <https://doi.org/10.5382/econgeo.4735>
- [6] Corbett, G.J. (2002). Structural controls to porphyry Cu-Au and epithermal Au-Ag deposits. *Australian Institute of Geoscientists Bulletin*, 36, 32-35.
- [7] Cannell, J., Cooke, D.R., Walshe, J.L., & Stein, H. (2005). Geology, mineralization, alteration, and structural evolution of the El Teniente porphyry Cu-Mo deposit. *Economic Geology*, 100(5), 979-1003. <https://doi.org/10.2113/gsecongeo.100.5.979>
- [8] Keith, J.D., Christiansen, E.H., & Carten, R.B. (1993). The genesis of giant porphyry molybdenum deposits. *Giant Ore Deposits*, 2, 285-317. <https://doi.org/10.5382/SP.02.07>
- [9] Piquer, J., Sanchez-Alfaro, P., & Pérez-Flores, P. (2021). A new model for the optimal structural context for giant porphyry copper deposit formation. *Geology*, 49(5), 597-601. <https://doi.org/10.1130/G48287.1>
- [10] Browne, P.R.L. (1978). Hydrothermal alteration in active geothermal fields. *Annual Review of Earth and Planetary Sciences*, 6, 229-248. <https://doi.org/10.1146/annurev.ea.06.050178.001305>
- [11] Adamia, S., Zakariadze, G., Chkhotua, T., Sadradze, N., Tsereteli, N., Chabukiani, A., & Gventsadze, A. (2011). Geology of the Caucasus: A review. *Turkish Journal of Earth Sciences*, 20(5), 489-544. <https://doi.org/10.3906/yer-1005-11>
- [12] Moritz, R., Melkonyan, R., Selby, D., Popkhadze, N., Gugushvili, V., Tayan, R., & Ramazanov, V. (2016). Metallogeny of the Lesser Caucasus: From arc construction to post-collision evolution. *Tectonics and Metallogeny of the Tethyan Orogenic Belt*, 19, 157-192. <https://doi.org/10.5382/SP.19.06>
- [13] Pejatović, S. (1971). Doğu Karadeniz-Küçük Kafkasya bölgesindeki metalojenik zonlar ve bunların metalojenik özellikleri. *Bulletin of the Mineral Research and Exploration*, 77, 10-21.
- [14] Kangarli, T. (2024). Minerageny of minerals of the south-eastern end of the Lesser Caucasus (Garabagh and East Zangazur, Azerbaijan). *Geomining: Systems and Decision-Oriented Perspective*, 109-120. https://doi.org/10.1007/978-3-031-70725-4_8
- [15] Imamverdiyev, N.A., Orudzhov, A.I., Valiyev, A.A., & Mursalov, S.S. (2022). Petro-geochemical features of the Bajocian island-arc volcanism in the Lesser Caucasus (Azerbaijan). *Journal of Geology, Geography and Geoecology*, 31(2), 280-292. <https://doi.org/10.15421/112226>
- [16] Aliyeva, E.G., & Guliyev, E.Kh. (2025). Geochemical and mineralogical characteristics of Upper Cretaceous sediments in the Lok-Karabakh zone (Azerbaijan): Implications for provenance, paleoweathering, paleoclimate and reservoir prediction. *SOCAR Proceedings*, 1, 3-8. <https://doi.org/10.5510/OGP20250101036>
- [17] İsmayıl, C., Arık, F., Özen, Y., & Bayramov, A. (2021). Geochemical, mineralogical and sulfur isotopic evidence on the genesis of the Gadir Au-Ag-Cu-Pb-Zn deposit (NW Azerbaijan), Lesser Caucasus. *Arabian Journal of Geosciences*, 14(13), 1298. <https://doi.org/10.1007/s12517-021-07520-6>
- [18] Babazadeh, V.M., Makhmudov, A.I., & Ramazanov, V.G. (1990). *Porphyry copper and molybdenum deposits*. Baku, Azerbaijan: Azerbaijan Publication, 377 p.
- [19] Chen, Z., Zhang, L., Wan, B., Wu, H., & Clevens, N. (2011). Geochronology and geochemistry of the Wunugetushan porphyry Cu-Mo deposit in NE China and their geological significance. *Ore Geology Reviews*, 43(1), 92-105. <https://doi.org/10.1016/j.oregeorev.2011.08.007>
- [20] Li, N., Chen, Y.J., Pirajno, F., & Ni, Z.Y. (2013). Timing of the Yuchiling giant porphyry Mo system and implications for ore genesis. *Mineralium Deposita*, 48(4), 505-524. <https://doi.org/10.1007/s00126-012-0441-4>

Геологічна будова та металогенічна еволюція порфірової Cu-Мо системи Демірлі, Малий Кавказ, Азербайджан

Н. Пашаєв, С. Ібрагімова, М. Абдулла-зада

Мета. Порфірова Cu-Мо система Демірлі, локалізована в юрських вулканічних і вулканогенно-уламкових товщах та просторо-во пов'язана з Джангатазьким гранітоїдним плутоном (Малий Кавказ, Азербайджан), є важливим об'єктом для переоцінки її залишкового мінерально-сировинного потенціалу з використанням матеріалів попередніх геологорозвідувальних робіт і результатів нових досліджень, розпочатих у 2024 році.

Методика. Інтегровано матеріали попереднього геологічного картування та геологорозвідувальних робіт 1965-1989 років і наступних етапів досліджень із оцифрованими архівними даними буріння та опробування, результатами літолого-структурного картування масштабу 1:1000 на площі 1.97 км², систематичного опробування зон гідротермальних змін і матеріалів, пов'язаних із гірничими роботами, реверсивно-циркуляційного буріння, виконаного у 2024 році, а також 3D геологічного моделювання в Leapfrog Geo та Micromine. Для уточнення просторової будови мінералізованої системи використано архівні геофізичні та геохімічні дані, зокрема результати магнітних досліджень, електричних методів, включаючи метод викликаної поляризації, та літохімічного опробування.

Результати. Мінералізація зосереджена в апікальних і крайових частинах багатопазного гіпібасального інтрузивного комплексу. Вона локалізована вздовж розломних коридорів NW-SE та близького до N-S простягання, пов'язаних із системою глибинного розлому Гілятаг. Гідротермальні зміни представлені інтенсивною силіцифікацією (вторинними кварцитами), а також кварц-серіцитовими, кварц-каолінітовими та кварц-хлоритовими асоціаціями, які супроводжуються штокверковими прожилками та вкрапленою сульфідною мінералізацією. У поверхневих пробах і пробах, відібраних у межах гірничих виробок, вміст Cu зазвичай становить близько 0.1-0.7%, при цьому локально фіксуються підвищені концентрації Мо. Архівні дані свідчать про значну вертикальну протяжність мінералізованого інтервалу, приблизно 200-300 м, і широкий аномальний ореол, характерний для порфірової прожилково-вкрапленої мінералізації.

Наукова новизна. Запропоновано комплексну переінтерпретацію геологічної будови родовища, яка поєднує еволюцію інтрузивного комплексу, структурну реактивацію, архітектуру гідротермальних змін і результати 3D геологічного моделювання, що дає змогу уточнити пошуково-розвідувальну модель порфірової Cu-Мо системи Демірлі.

Практична значимість. Отримані результати обґрунтовують проведення пошуково-розвідувального буріння на продовженні основних розломних коридорів і в межах апікальних інтрузивних та гідротермально змінених зон, а також дають змогу використовувати характер гідротермальних змін як пошукові вектори під час програм оконтурювання та уточнення ресурсів.

Ключові слова: порфірова Cu-Мо система; Малий Кавказ; Лок-Карабаська зона; гіпібасальний плутон; викликана поляризація; гідротермальні зміни; штокверк; 3D геологічне моделювання

Publisher's note

All claims expressed in this manuscript are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.