Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources

Crossref

DOI: 10.31643/2027/6445.07
Earth sciences

A study of the geochemical features of the Nurkazgan copper-porphyry deposit

[1] Kopobayeva A.N., [1] Zharylgapov Ye.Ye., [2]Ulgibayeva B.S., [1*]Amangeldikyzy A., [1*]Askarova N.S., [1*]Kabyken A.B.

[1]*Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan*
[2]*LLP Geotek, Karaganda, Kazakhstan*

**Corresponding author's email: a.amangeldykyzy@ktu.edu.kz*

Received: *July 12, 2025*
Peer-reviewed: *July 21, 2025*
Accepted: *September 22, 2025*

ABSTRACT
Porphyry copper deposits are the source of most of the world's copper, molybdenum and significant amounts of gold. This makes them a major focus of scientific research due to their economic significance. The article is devoted to the study of the geochemistry of host rocks and copper-porphyry ores at the Nurkazgan deposit. It identifies geochemical criteria for the distribution of gold in copper-porphyry systems, as well as refines ore formation mechanisms in order to improve predictive criteria. The results were obtained by interpreting analytical data obtained using the ICP-OES (ICP-AES) method and the geostatistical method. Based on this research, key factors have been identified that determine the distribution of element content. As a result of studying the distribution of REEs in the host rocks, conditions for ore formation were established: the deposit has an igneous origin with signs of prolonged fractionation of the magma; a negative Eu anomaly confirms the involvement of plagioclase fractionation typical of medium and acidic magmas; LREE enrichment indicates an evolved magma involving the continental crust, while moderate depletion of HREE indicates a deep source of magmatism with residual garnet involvement. The established strong positive correlation between REES indicates a single geochemical process and reflects the primary magmatic identity. A porphyry system with a deep magmatic source has been revealed, where ore fluids are separated from the residual melt, which is already depleted in Eu but enriched in LREEs and metals.

Keywords: geochemistry, geological processes, mineralization zones, distribution of elements, localization of minerals, ore-forming processes, copper mineralization, ore deposits.

Information about authors:

Kopobayeva Aiman Nygmetovna	*PhD, associate professor of the Geology and Exploration MD Department of Abylkas Saginov Karaganda Technical University, 100000, Karaganda, Kazakhstan. E-mail: kopobayeva@inbox.ru; ORCID ID: https://orcid.org/0000-0002-0601-9365*
Zharylgapov Yerassyl Yerboluly	*Master's student of the Geology and Exploration MD Department of Abylkas Saginov Karaganda Technical University, 100000, Karaganda, Kazakhstan. E-mail: erasyl.zharylgapov@mail.ru; ORCID ID: https://orcid.org/0009-0001-8389-4710*
Ulgibayeva Begim Sarkytbaykyzy	*Geologist, LLP Geotek, 100027, Karaganda, Republic of Kazakhstan. E-mail: begimay.97@mail.ru; ORCID ID: https://orcid.org/0009-0003-1644-4183*
Amangeldikyzy Altynay	*PhD, acting associate professor of the Geology and Exploration MD Department of Abylkas Saginov Karaganda Technical University, 100000, Karaganda, Kazakhstan. E-mail: a.amangeldykyzy@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-6665-8804*
Askarova Nazym Srazhadinkyzy	*PhD, senior lecturer of the Department of Geology and Exploration of Mineral Resources, Abylkas Saginov Karaganda Technical University, 100027, Karaganda, Kazakhstan. E-mail: n.askarova@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-2103-6198*
Kabyken Aidyn Bakytzhanuly	*Doctoral student of the Geology and Exploration MD Department of Abylkas Saginov Karaganda Technical University, 100000, Karaganda, Kazakhstan. E-mail: aidynkabyken@yandex.ru; ORCID ID: https://orcid.org/0009-0008-2020-6141*

Introduction

Copper is a critical and vital component in various modern green technologies [[1], [2]]. In this regard, molybdenum-copper deposits in veined ores or the so-called porphyry copper deposits are becoming increasingly important. Copper porphyry deposits are key sources of non-ferrous metals and precious metals, and play an important role in mining, stimulating research and exploration [[3],[4],[5],[6],[7],[8]]. Significant are ore zones containing significant concentrations of gold and silver, which act as both associated components and valuable target products [8]. These deposits, which are often characterized by poorer ores compared to pyrites, skarns, and veins, should have sufficiently large reserves of copper ore and be mined using open-pit methods to be profitable for development. The appeal of this type of deposit is also determined by the possibility not only to organise open-cast mining, but also to extract complex ores containing valuable impurities such as gold, silver, rhenium, selenium, tellurium, bismuth, and others.

The low cost of open-pit copper mining and the complex nature of ores justify the industry's focus on this type of deposit as a main source of copper production, not only in the past and present, but also in the future. This is why many geologists around the world are interested in open-pit mining. For example, Ferraq et al. (2024) conducted a comprehensive geochemical and geochronological study of the Imourkhsen porphyry deposit in Morocco, showing the relationship between empirical data and the stages of large-scale magmatism [9]. Studies on the analysis of Côte Gold-type deposits in Canada [10] have revealed typical alteration zones and their geochemical markers, which are important for predicting ore formation. Chinese scientists [11] have provided new data on U-Pb and Hf isotopes, indicating magmatic intrusions in a post-collision context at the Wubaduolai deposit. Zhangetal. (2024) [12], through the Sr-Nd isotope analysis of Sinondo granitoids in Tibet, confirmed the genetic link between magmatism and Ag-Pb-Zn enrichment. All this indicates that the integration of the latest isotopic, geochemical, and geochronological data is crucial for understanding porphyry ore formation processes and can be applied to systems such as the Nurkazgan deposit.

In Kazakhstan, copper-porphyry deposits such as Aktogay, Aidarly, Bozshakol, and Koksai are of significant importance for the extraction of copper and other precious metals. These deposits contain low levels of copper, but have substantial reserves. Moreover, spatial analysis of precious metal distribution contributes to the development of three-dimensional ore body models, enabling more accurate prediction of metal content at different levels within a deposit. This is crucial for the economic evaluation of a deposit, planning of mining operations, and selection of optimal mining methods [13].

It is also important to take into account that the localization of gold and silver can be caused not only by primary ore formation processes but also by secondary hydrothermal processes that redistribute metals within ore bodies. Understanding these processes helps to make a more accurate interpretation of geological data and increase efficiency.

The Nurkazgan deposit is of particular interest due to its unique geological and structural characteristics. The development of this deposit is associated with several tasks, including the high variability of the precious metal content, challenging extraction conditions, and the need for environmentally sound technologies for ore processing. Geochemical analysis of the composition of ores and their structural features makes it possible not only to understand the processes of ore formation, but also to significantly increase the efficiency of prospecting operations. One of the directions of its solution is to improve the geological and genetic foundations of forecasting, taking into account which forecasting and prospecting models of ore regions and fields are built, to modernize methods and technologies of forecasting, prospecting and evaluation of deposits and, above all, hidden ones, that is, those that do not go out to the daytime surface.

The purpose of the study is to identify geochemical features and to study the distribution of gold and silver in copper-porphyry ores at the Nurkazgan deposit, in order to determine the factors that influence ore formation and conditions for deposit formation, with a view to increasing the efficiency of exploration operations. Scientific knowledge of ore-forming processes is of direct practical significance for improving the effectiveness of mining operations in Kazakhstan. This work is based on materials published and collected by the authors.

Experimental part

Methodology. Analytical and published data were used to study the geochemical characteristics of the deposit. When studying the distribution of gold, silver, and other elements in the ore of the Nurkazgan deposit, complex geochemical studies were conducted using the interpretation of data with geostatistical methods. Analytical work was performed in the laboratory of EcoNus LLP in Karaganda, utilizing ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) for eight elements (Ag, As, Au, Cu, Mo, Pb, S, and Zn), atomic absorption analysis for gold assays, and published data on the chemical makeup of host rocks, which were subsequently interpreted by the authors.

Samples of ore and host rock from various zones of the studied deposit were collected. These samples were subjected to a detailed geochemical analysis to determine the concentrations of major and trace elements and their spatial distribution. The analysis was conducted in the laboratory of EkoNus LLP in Karaganda. The depth distribution of elements was analyzed based on drilled wells, which made it possible to identify the enrichment zones of copper, gold, and silver. Standard classification diagrams and ratios such as Sr/Y and Eu/Eu* were used to interpret the geochemical data and analyze the magma source and ore-forming processes.

Geological characteristics of the deposit. The Nurkazgan deposit is located in the Bukhar-Zhyrau district of the Karaganda region, 30 km north of Karaganda and 10 km northeast of Temirtau. It is also 2.5 km away from the northern shore of the Samarqand reservoir. The closest railway station is Murza (Aktau), which is 8 km away. The nearest highway is 3-4 km to the north-west and the Astana-Almaty highway is about 7 km west (Fig. 1).

Figure 1 – Overview map of the Nurkazgan deposit area

The Nurkazgan deposit has a complex geological structure, owing to its location within the Karaganda tectonic block, which is part of the Hercynian fold belt. The geological composition of the deposit includes sedimentary, volcanic, and intrusive rock formations from the Paleozoic era. Sedimentary deposits comprise mudstones, silts, sandstones, and conglomerates. Volcanic rocks include andesite, basalt, and their associated tuff formations. Intrusive rocks include granite, diorite, and gabbro. The deposit is classified as a porphyry copper deposit and contains significant reserves of copper, gold, and lead. The primary ore minerals of the deposit are chalcopyrite, bornite, pyrite, and magnetite. Associated minerals include quartz and calcite. The deposits have a predominantly lenticular or laminated shape and occur at depths ranging from 500 to 600 m. They are associated with fault zones and fractures. On the surface, there is an oxidation zone enriched in secondary copper minerals that makes it potentially suitable for the extraction of oxidised ores [14].

The Nurkazgan deposit consists of several sites, each with its own geological characteristics and level of industrial development. The ore-bearing rocks in the areas of active mining include granodiorite-porphyry, quartz-dioritic porphyry, quartz diorite and diorite (Fig. 2).

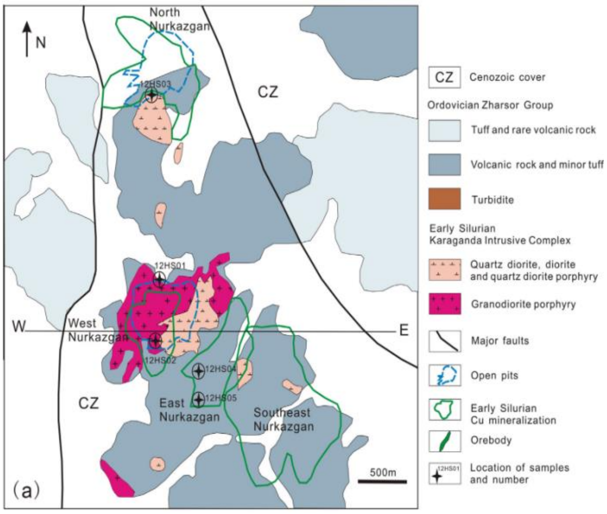


Figure 2 – Geological map of the Nurkazgan deposit (based on Yakubchuk et al. (2012), with modifications) [15]

The main feature of the deposit is the central ore-bearing area, which contains the main reserves of copper and related elements such as gold, silver, and molybdenum. The most significant occurrences of porphyry-type copper mineralization are observed here, primarily in the form of disseminated and vein-disseminated deposits. The central location is being actively explored and forms the core of all operational activities within the field. The western section of the area is adjacent to the main area and is characterized by dispersed mineralization. This area has a lower concentration of useful components compared to other parts of the site, but it has been identified as promising for further exploration and potential expansion of ore reserves. The eastern section contains ore bodies with predominant copper-pyrite mineralization, with some areas showing increased gold content. This makes this part of the site interesting for the complex processing of raw materials. The southern area has a high copper content, reaching up to 4% in certain locations. In this region, ore bodies often have a complicated structure formed through the influence of tectonic processes. Both open-pit and underground mining operations are taking place in the southern area. The northern section is poorly studied, but geophysical and geochemical data indicate the presence of potentially promising structures that could contain ore bodies at greater depths. It is considered a potential target for future exploration efforts. In addition to the primary ore zones, the deposit has overburden areas and spent quarries that have been used to store overburden rock and man-made structures.

Thus, the Nurkazgan field is a complex, multi-stage structure that combines both currently developed areas and promising areas for future exploration and development.

Results and Discussion

For a detailed geochemical analysis, published chemical composition data on 14 samples of intrusive rocks from the Nurkazgan deposit were used [16]. Based on the results obtained, a TAC diagram (Fig. 3) was constructed to determine the types of intrusive rocks. The studied igneous rocks demonstrate a wide range of SiO_2 content (52.78-68.92%) and varying potassium content (1.08-8.62%). Intrusive rocks associated with porphyritic copper mineralization are characterized by a high content of SiO_2 (65.45-68.92%) and potassium (6.16-8.62%), and all samples are classified as granitoids and located in the granite field (Fig. 3). In comparison, the intrusive rocks associated with copper-gold mineralization have a lower content of SiO_2 (52.78-65.15%) and K_2O (1.08-6.25%). They form a wide field on the diagram covering the range from diorites to monzonites (Fig. 3).

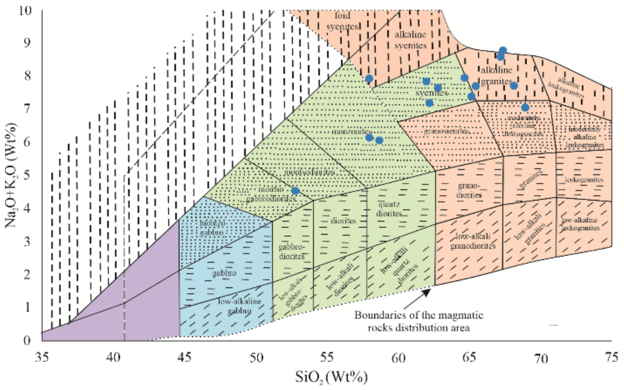


Figure 3 – TAC diagram, definition of rock types

To determine the sources of ore formation, graphs of the distribution of rare earth elements are constructed (Fig. 4). Rare earth elements are indicated on the X-axis, and their contents in rocks are normalized to the UCC on the Y-axis. (Taylor and McLennan, 1985). The characteristic geochemical features of igneous rocks are established. In most cases, there is a predominance of light rare earth elements over heavy ones, which may indicate processes of plagioclase crystallization or post-magmatic differentiation. Samples from 12HSO$_4^{-4}$* to 12HSO$_5^{-4}$ (Fig. 4, c), 12HSO$_1^{-2}$** (Fig. 4, b) clearly show a positive Eu anomaly. The content is significantly higher than in neighboring Sm and Gd. This may be the result of reduced conditions, the crystallization of ores in plagioclase-containing rocks, and fluid action [[16],[17]], as well as 12HSO$_3^{-1}$* shows a slight increase in Eu, which may indicate the absence of a pronounced anomaly.

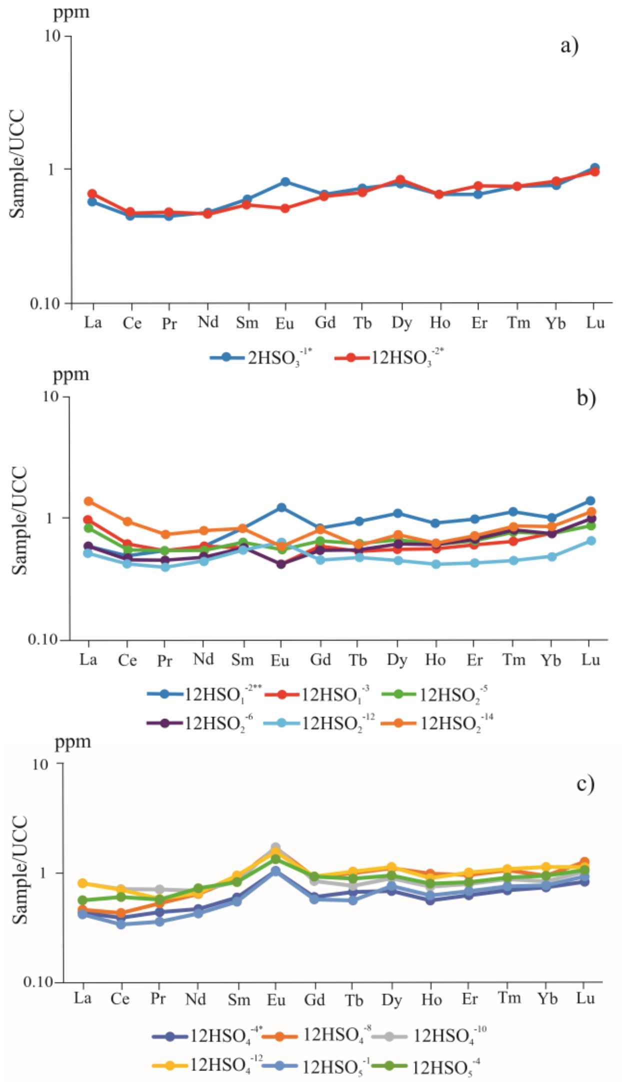


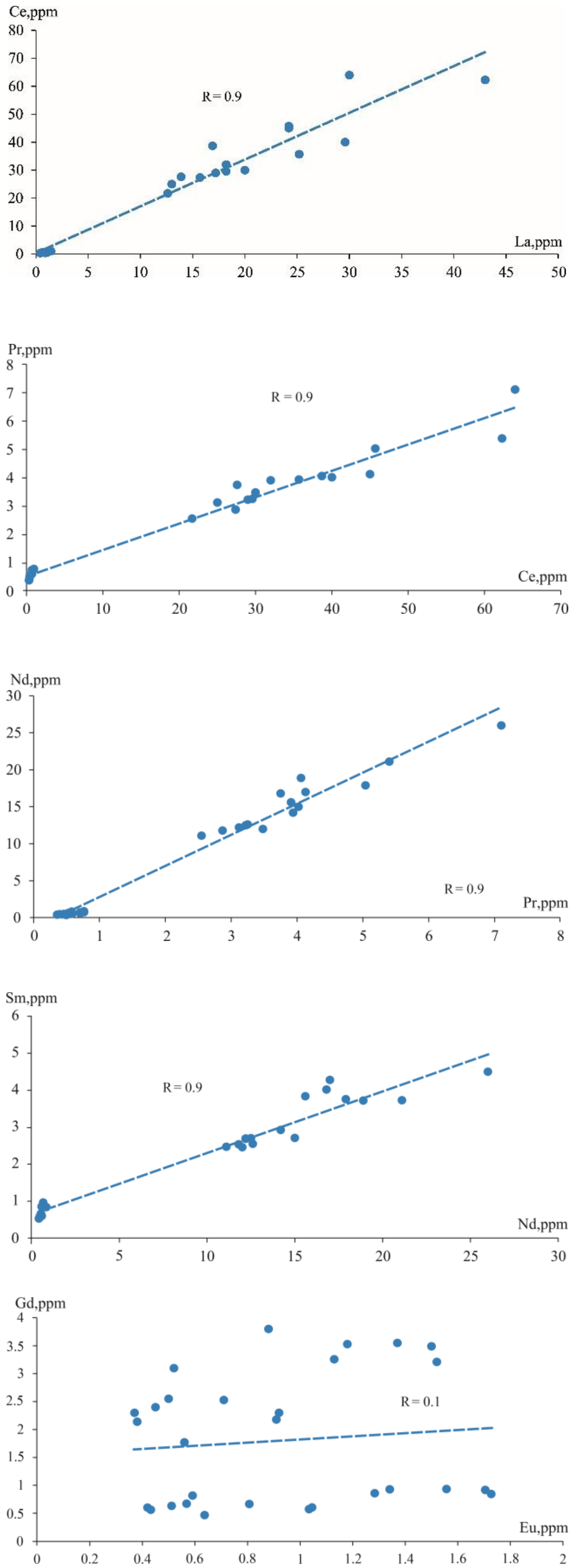
Figure 4 – Distribution of rare earth elements in the Nurkazgan deposit

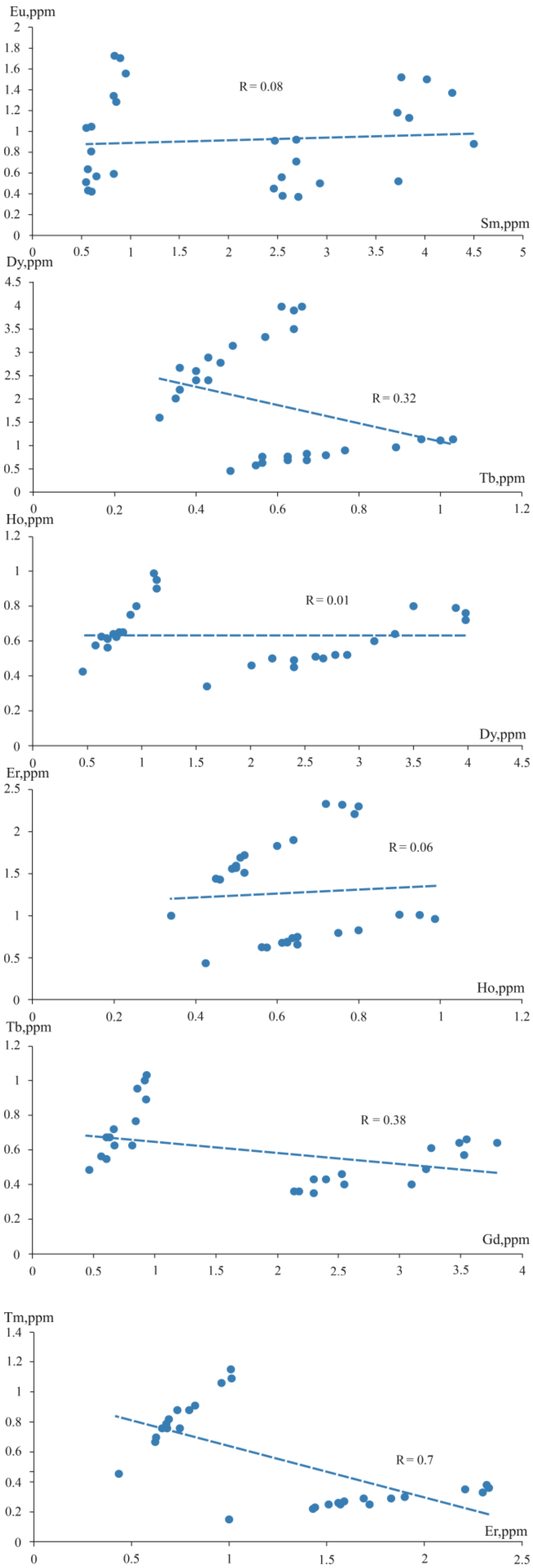
The europium anomaly manifests itself as a deviation of the europium concentration from the general trend of the REE distribution. The diagrams show that the europium content is noticeably lower in sample 12HSO$_3^{-2}$* sample (Fig. 4, a), as well as samples from 12HSO$_1^{-3}$ to 12HSO$_2^{-14}$ (Fig. 4, b), than in the neighbouring elements, samarium or gadolinium. This indicates a negative europium anomaly.

Such anomalies are typical of igneous rocks that have undergone differentiation, especially granitoids. In addition, a negative europium anomaly may be associated with a high degree of partial melting of crustal material, resulting in europium remaining in the residual rock rather than enriching the magma [[16], [17]]. The influence of hydrothermal processes may also contribute to additional europium leaching. As a result of studying the REE distribution at the Nurkazgan deposit, it was found that light REEs (L-REE) enrichment occurs, with La, Ce, Pr and Nd being noticeably enriched relative to VCC. This indicates the fractionated nature of the source, and possibly the participation of crustal material or prolonged magma differentiation. There is a smooth decline in Sm to Lu (HREEs), heavy REE (Gd-Lu) are gradually decreasing, indicating a moderate depletion in HREE, which may indicate the residual presence of garnet in the source. A clearly pronounced negative Eu anomaly is visible on graphs, with Eu/Eu<1 indicating the fractionation of plagioclase, which selectively accumulates Eu^{2+}. This suggests that the rocks formed after plagioclasic crystallization or from a depleted melt in europium [[18], [19], [20]].

For the effective development of a field, it is essential not only to consider the identified patterns but also to identify additional parameters that influence the distribution of valuable elements. This approach will provide a more accurate understanding of ore formation processes [[21], [22]].

An analysis of the relationships between rare earth elements shows (Fig. 5) that most of them exhibit a high degree of correlation (R≤0,7) within their groups: Ce-La, Pr-Ce, Nd-Pr, Sm-Nd, Lu-Yb, Tm-Er, Yb-Tm. This indicates similar mechanisms of their fractionation and deposition in geochemical processes [[23], [24]]. The most pronounced relationships are observed between elements of the light group, such as La, Ce, Pr, and Nd. These elements indicate their joint migration and accumulation in geological systems. Medium rare earth elements, including Sm, Gd and Tb, exhibit less pronounced correlations. This may be due to their more complex behavior during crystallization processes. Eu has a low correlation with most other elements. This is probably due to its ability to redox changes affecting the degree of its accumulation. Heavy rare earth elements, such as Dy, Ho, Er and Tm, show less pronounced dependencies, and their relationship to lighter elements varies. Some of these elements show weak or negative correlations, which may be a reflection of the processes of selective separation during hydrothermal alteration of rocks.





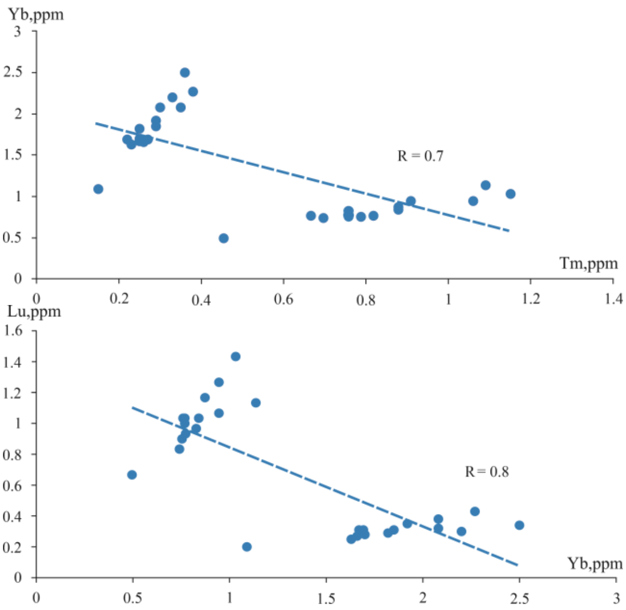


Figure 5 – Correlation between rare earth elements in rocks from the Nurkazgan deposit

In general, the results of the analysis confirm the patterns of behavior of rare earth elements in natural systems corresponding to known geochemical models for their migration and deposition. However, low correlation coefficients between individual elements indicate the influence of local factors such as changes in redox conditions and differentiation of magmatic sources.

The obtained results of ICP-OES (ICP-AES), based on the concentrations of elements (Ag, Au, Cu), were used to plot changes in the content of copper (Cu) and gold (Au) as a function of depth (Fig. 6).

Geochemical analysis has established how the content of these elements varies in different layers of a deposit. For example, copper exhibits high concentrations in the upper horizons, which may be associated with zones of oxidation and redistribution of metals under the influence of surface processes. However, with increasing depth, its content may either gradually decrease or reach local peaks associated with ore bodies and zones of sulfide mineralization.

The content of precious and non-ferrous metals in the well opening is shown in Table 1.

Gold, unlike copper, often exhibits a more stable distribution. However, at some points, its concentration may increase with depth. If the graph shows that gold has a local maximum at a certain depth (e.g., 300–400 m), this may indicate the presence of gold ore zones formed as a result of hydrothermal processes.

Table 1 – ICP-OES (ICP-AES) analysis results for (Ag, Au, Cu)

No.	Sample number	Interval		Elements		
		from	to	Ag, g/t	Cu, g/t	Au, g/t
1	1	0	1	2.324	8.62	0.846
2	2	1	2	0.78	3.49	1.024
3	3	2	3	1.452	6.34	0.674
4	4	3	4	6.035	15.48	0.558
5	5	4	5	1.314	2.51	0.116
6	6	5	6	1.356	2.26	0.095
7	7	6	7	1.686	5.53	0.533
8	8	7	8	1.731	5.72	0.253
9	9	8	9	0.99	2.14	0.163
10	10	9	10	0.228	0.67	0.055

In addition, the ratio of Cu and Au at different depths may indicate their genetic relationship. If, for example, concentrations of copper and gold grow simultaneously at certain levels, this indicates that the metals could have been deposited together during ore formation. However, if their distribution is different, gold may be associated with other minerals, such as quartz or pyrite.

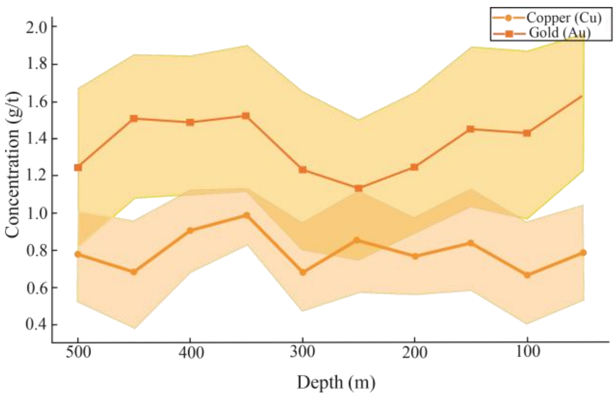


Figure 6 – Changes in the concentrations of copper (Cu) and gold (Au) with depth

The analysis of this distribution is important for assessing the depth of the deposit. It allows us to identify the most promising areas for future development and refine the mining strategy.

Conclusions

The geochemical analysis made it possible to identify patterns in the distribution of rare earth elements within the intrusive rocks at the deposit, which made it possible to determine the sources of ore formation and the conditions under which they formed. The deposit is of igneous origin with signs of long-term melt fractionation. The negative Eu anomaly confirms involvement of plagioclase fractionation typical of intermediate and acid magmas. LREE enrichment indicates evolved magma with participation of continental crust, while moderate depletion of HREE indicates a deep origin or influence of garnet from the source.

From the correlation analysis of the REE distribution, it has been established that REE behavior is consistent during rock formation and the uniformity of geochemical conditions for rock formation. REEs were jointly fractionated during crystallization and did not undergo significant secondary redistribution, such as hydrothermal leaching, but retained their original magmatic characteristics and identity. A positive linear relationship (R~0.9) suggests a single source for REEs; the same REE behavior during magma differentiation, with no strong fractionation of individual REEs relative to others, except possibly Europium.

The geochemical analysis of the copper-porphyry ores of the Nurkazgan deposit revealed that copper and silver demonstrate a high degree of correlation, indicating their joint mineralogical association in the composition of sulfide phases, mainly chalcopyrite and bornite. Gold is characterized by a moderate bond with copper, which is typical for gold-copper porphyry systems, but its distribution is largely determined by secondary hydrothermal processes.

Deep profiles have shown that copper is more concentrated in near-surface zones, where oxidation and leaching processes dominate. At the same time, gold exhibits a relatively stable distribution with local peaks at certain depths, which may indicate the presence of hidden gold ore bodies. This is important for planning mining operations and further exploration.

The established patterns of metal distribution in ores allowed us to reconstruct the processes of ore formation, which is important for predicting copper porphyry deposits.

Conflict of interest. On behalf of all authors, the corresponding author declares that there is no conflict of interest.

CRediT author statement: **A. Kopobayeva**: Writing - Original Draft, Conceptualization, Methodology, Supervision; **Ye. Zharylgapov**: Data curation, Investigation, Writing draft preparation; **B. Ulgibayeva**: Visualization, Investigation, Resources; **A. Amangeldikyzy**: Writing - Review & Editing, Visualization; **A. Askarova:** Visualization, Software, Validation, Software; **A. Kabyken:** Software, Formal analysis.

Cite this article as: Kopobayeva AN, Zharylgapov YeYe, Ulgibayeva BS, Amangeldikyzy A, Askarova NS, Kabyken AB. A study of the geochemical features of the Nurkazgan copper-porphyry deposit. Kompleksnoe Ispolzovanie Mineralnogo Syra = Complex Use of Mineral Resources. 2027; 340(1):67-76. https://doi.org/10.31643/2027/6445.07

Нұрқазған мыс-порфирлі кен орнының геохимиялық ерекшеліктерін зерттеу

[1] Копобаева А. Н., [1] Жарылғапов Е.Е, [2] Үлгібаева Б. С., [1]Амангелдіқызы А.,
[1]Асқарова Н. С., [1]Қабыкен А.Б.

[1]Әбілқас Сағынов Атындағы Қарағанды Техникалық Университеті, Қарағанды, Қазақстан
[2] Геотек ЖШС, Қарағанды, Қазақстан

Мақала келді: *12 шілде 2025*
Сараптамадан өтті: *21 шілде 2025*
Қабылданды: *22 қыркүйек 2025*

ТҮЙІНДЕМЕ
Порфирлі мыс кен орындары дүние жүзіндегі мыстың, молибденнің және алтынның едәуір бөлігінің негізгі көзі болып табылады. Бұл олардың экономикалық маңыздылығына байланысты ғылыми зерттеудің негізгі объектісіне айналдырады. Мақала Нұрқазған кен орнының негізгі жыныстары мен порфирлі мыс кендерінің геохимиясын зерттеуге арналған. Онда порфирлі мыс жүйелерінде алтынның таралуының геохимиялық критерийлері анықталады, болжау критерийлерін жетілдіру мақсатында кен түзілу механизмдері нақтыланады. Нәтижелер ICP-OES (ICP-AES) және геостатистикалық әдістерді қолдану арқылы алынған аналитикалық деректерді интерпретациялау арқылы алынды. Осы зерттеу негізінде элементтердің мөлшері бойынша таралуын анықтайтын негізгі факторлар анықталды. Негізгі жыныстардағы СЖЭ таралуын зерттеу нәтижесінде кен түзілу жағдайлары анықталды: кен орны магманың ұзақ мерзімді фракциялану белгілері бар магмалық тектi; теріс Eu аномалиясы аралық және қышқыл магмаларға тән плагиоклазды фракциялануды қатысатынын дәлелдейді; СЖЭ-ның байытылуы континенттік жер қыртысындағы магманың эволюциясын көрсетеді, ал СЖЭ-ның қалыпты азаюы қалдық гранатпен магматизмнің терең көзін көрсетеді. СЖЭ арасындағы күшті оң корреляция бір геохимиялық процесті көрсетеді және бастапқы магмалық сәйкестікті көрсетеді. Терең магмалық көзі бар порфир жүйесі ашылды, онда кен сұйықтары Ес-да таусылған, бірақ сирек жер элементтері мен металдарға байытылған қалдық балқымадан бөлінеді.

Түйін сөздер: геохимия, геологиялық процестер, минералдану аймақтары, элементтердің таралуы, пайдалы қазбалардың локализациясы, кен түзу процестері, мыстың минералдануы, кен орындары.

Авторлар туралы ақпарат:

Копобаева Айман Ныгметовна	*PhD, Геология және пайдалы қазбалар кен орындарын барлау кафедрасының қауымдастырылған профессоры, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, 100000, Қарағанды, Қазақстан. E-mail: kopobayeva@inbox.ru; ORCID ID: https://orcid.org/0000-0002-0601-9365*
Жарылғапов Ерасыл Ерболұлы	*Геология және пайдалы қазбалар кен орындарын барлау кафедрасының магистранты, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, 100000, Қарағанды, Қазақстан. E-mail: erasyl.zharylgapov@mail.ru; ORCID ID: https://orcid.org/0009-0001-8389-4710*
Улгибаева Бегім Сарқытбайқызы	*Геолог, ЖШС Geotek, 100027, Қарағанды, Қазақстан. E-mail: begimay.97@mail.ru; ORCID ID: https://orcid.org/0009-0003-1644-4183*
Амангелдіқызы Алтынай	*PhD, Геология және пайдалы қазбалар кен орындарын барлау кафедрасы доцентінің міндетін атқарушы, Әбілқас Сағынов атындағы Қарағанды техникалық университеті КеАҚ, 100000, Қарағанды, Қазақстан. E-mail: a.amangeldykyzy@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-6665-8804*
Асқарова Назым Сражадинқызы	*PhD, Геология және пайдалы қазба кен орындарын барлау» кафедрасының аға оқытушысы, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, 100000, Қарағанды. Қазақстан. E-mail: n.askarova@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-2103-6198*
Қабыкен Айдын Бақытжанұлы	*Геология және пайдалы қазбалар кен орындарын барлау кафедрасының докторанты, Әбілқас Сағынов атындағы Қарағанды техникалық университет, 100000, Қарағанды, Қазақстан. E-mail: aidynkabyken@yandex.ru; ORCID ID: https://orcid.org/0009-0008-2020-6141*

Изучение геохимических особенностей Нурказганского медно-порфирового месторождения

[1] Копобаева А. Н., [1] Жарылгапов Е. Е., [2] Ульгибаева Б. С., [1] Амангелдіқызы А.,
[1] Асқарова Н. С., [1]Кабыкен А. Б.

[1] Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан
[2] ТОО Геотек, Караганда, Казахстан

Поступила: *12 июля 2025*
Рецензирование: *21 июля 2025*
Принята в печать: *22 сентября 2025*

АННОТАЦИЯ
Медно-порфировые месторождения являются источником большей части мировых запасов меди, молибдена и значительного количества золота. Это делает их основным объектом научных исследований из-за их экономической значимости. Статья посвящена изучению геохимии вмещающих пород и медно-порфировых руд месторождения Нурказган. В нем определены геохимические критерии распределения золота в медно-порфировых системах, а также уточнены механизмы рудообразования с целью улучшения прогнозных критериев. Результаты были получены путем интерпретации аналитических данных, полученных с использованием метода ICP-OES (ICP-AES) и геостатистического метода. На основе этого исследования были определены ключевые факторы, определяющие распределение содержания элементов. В результате изучения распределения РЗЭ во вмещающих породах были установлены условия для рудообразования: месторождение имеет магматическое происхождение с признаками длительного фракционирования магмы; отрицательная аномалия Eu подтверждает участие плагиоклазового фракционирования, характерного для средне- и кислых магм; Обогащение РЗЭ указывает на эволюцию магмы в континентальной коре, в то время как умеренное истощение РЗЭ указывает на глубинный источник магматизма с остаточным участием граната. Установленная сильная положительная корреляция между РЗЭ указывает на единый геохимический процесс и отражает первичную магматическую идентичность. Была обнаружена порфировая система с глубинным магматическим источником, где рудные флюиды отделяются от остаточного расплава, который уже истощен в Ес, но обогащен редкоземельными элементами и металлами.

Ключевые слова: геохимия, геологические процессы, зоны минерализации, распределение элементов, локализация минералов, процессы рудообразования, медная минерализация, месторождения.

Информация об авторах:

Копобаева Айман Ныгметовна — *PhD, ассоциированный профессор кафедры Геология и разведка МПИ, Карагандинский технический университет имени Абылкаса Сагинова, 100000, Караганда, Казахстан. E-mail: kopobayeva@inbox.ru; ORCID ID: https://orcid.org/0000-0002-0601-9365*

Жарылгапов Ерасыл Ерболулы — *Магистрант кафедры Геология и разведка МПИ, Карагандинский технический университет имени Абылкаса Сагинова, 100000, Караганда, Казахстан. E-mail: erasyl.zharylgapov@mail.ru; ORCID ID: https://orcid.org/0009-0001-8389-4710*

Ульгибаева Бегим Саркытбайкызы — *Геолог, ТОО Геотек, 100027, Караганда, Казахстан. E-mail: begimay.97@mail.ru; ORCID ID: https://orcid.org/0009-0003-1644-4183*

Амангелдіқызы Алтынай — *PhD, и.о. доцента кафедры Геология и разведка МПИ, Карагандинский технический университет имени Абылкаса Сагинова, 100000, Караганда, Казахстан. E-mail: a.amangeldykyzy@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-6665-8804*

Аскарова Назым Сраджадиновна — *PhD, старший преподаватель кафедры Геология и разведка МПИ, Карагандинский государственный технический университет имени Абилкаса Сагинова, 100000, Караганда, Казахстан. E-mail: n.askarova@ktu.edu.kz; ORCID ID: https://orcid.org/0000-0002-2103-6198*

Кабыкен Айдын Бакытжанулы — *Докторант кафедры Геология и разведка МПИ, Карагандинский технический университет имени Абылкаса Сагинова, 100000, Караганда, Казахстан. E-mail: aidynkabyken@yandex.ru; ORCID ID: https://orcid.org/0009-0008-2020-6141*

References

[1]Sillitoe RH. Porphyry Copper Systems. Economic Geology. 2010; 105:3-41. https://doi.org/10.2113/gsecongeo.105.1.3

[2]Sun W, Huang RF, Li H, Hu YB, Zhang CC, Sun SJ, Zhang LP, Ding X, Li CY, Zartman RE, and etc. Porphyry deposits and oxidized magmas. Ore Geology Reviews. 2015; 65:97-131. https://doi.org/10.1016/j.oregeorev.2014.09.004

[3]Serykh VI, Kopobayeva AN. Patterns of distribution of rare metal deposits in Central Kazakhstan. News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences. 2019, 143-150. https://doi.org/10.32014/2019.2518-170X.18

[4]Windley BF, Xiao W. Ridge subduction and slab windows in the Central Asian Orogenic Belt: Tectonic implications for the evolution of an accretionary orogen. Gondwana Res. 2018; 61:73-87. https://doi.org/10.1016/j.gr.2018.05.003

[5]Xu XW, Li H, Peters SG, Qin KZ, Mao Q, Wu Q, Hong T, Wu C, Liang GL, Zhang ZF, and et al. Cu-rich porphyry magmas produced by fractional crystallization of oxidized fertile basaltic magmas (Sangnan, East Junggar, PR China). Ore Geology Reviews. 2017; 91:296-315. https://doi.org/10.1016/j.oregeorev.2017.09.020

[6]Fu Y, Cheng Q, Jing L, Ye B, Fu H. Mineral Prospectivity Mapping of Porphyry Copper Deposits Based on Remote Sensing Imagery and Geochemical Data in the Duolong Ore District, Tibet. Remote Sens. 2023; 15:439. https://doi.org/10.3390/rs15020439

[7]Liu C, Qiu C, Wang L, Feng J, Wu S, WangY. Application of ASTER Remote Sensing Data to Porphyry Copper Exploration in the Gondwana Region. Minerals 2023; 13:501. https://doi.org/10.3390/min13040501

[8]Orynbassarova E, Ahmadi H, Adebiyet B, Bekbotayeva A, Abdullayeva T, Beiranv andPour A, Ilyassova A, Serikbayeva E, Talgarbayeva D, Bermukhanova A. Mapping Alteration Minerals Associated with Aktogay Porphyry Copper Mineralizationin Eastern Kazakhstan Using Landsat-8 and ASTER Satellite Sensors. Minerals. 2025; 15:277. https://doi.org/10.3390/min15030277

[9]Ferraq M, Belkacim S, Cheng LZ, Davies JHFL, Perrot MG, Ben-Tami A, Bouabdellah M. New Geochemical and Geochronological Constraints on the Genesis of the Imourkhssen Cu±Mo±Au±Ag porphyry deposit (Anti-Atlas, Morocco): geodynamic and metallogenic implications. Minerals. 2024; 14(8):832. https://doi.org/10.3390/min14080832

[10] Kontak DJ, and et al. Alteration lithogeochemistry of the Archean porphyry-type Côté Gold Au(-Cu) deposit, Ontario, Canada: implications for exploration. Minerals. 2023; 15(3):256. https://doi.org/10.3390/min15030256

[11] Gao K, Zhang Z, Zhang L, Xu P, Yang Y, Wu J, Li Y, Sun M, Su W. Significance of Adakitic Plutons for Mineralization in Wubaduolai Copper Deposit, Xizang: Evidence from Zircon U-Pb Age, Hf Isotope, and Geochemistry. Minerals. 2025; 15(5):500. https://doi.org/10.3390/min15050500

[12] Zhang P, Li Z, Zhao F, Liu X. Petrogenesis and Tectonic Implications of the Granite Porphyry in the Sinongduo Ag-Pb-Zn deposit, Central Tibet: constraints from geochronology, geochemistry, and Sr-Nd isotopes. Minerals. 2024; 14(7):710. https://doi.org/10.3390/min14070710

[13] Cooke DR, Hollings P, Wilkinson JJ, Tosdal R. Geochemistry of porphyry deposits. Treatise on Geochemistry (Second Edition).2014; 13;357-381. https://doi.org/10.1016/B978-0-08-095975-7.01116-5

[14] Otchet s podschetom zapasov zoloto-mednyh rud Vostochnogo uchastka mestorozhdeniya Nurkazgan po sostoyaniyu na 01.01.2019 g. [Report on thecalculationofgold and copperore reserves in the Eastern section of the Nurkazgan depositas of 01.01.2019]. Nur-Sultan. (in Russ.).

[15] Yakubchuk A, Degtyarev K, Maslennikov V, Wurst A, Stekhin A, Lobanov K. Tectonomagmatic Settings, Architecture, and Metallogeny of the Central Asian Copper Province. Society of Economic Geologists. Inc. Special Publication. 2012; 16:403-432. https://doi.org/10.5382/SP.16.16

[16] Feng H, Seltmann R, Shen P, Chu X, Suo Q, Seitmuratova E, Shatov V. Hydrothermal rutile chemistry and U-Pb age fingerprinting of the formation of the giant Nurkazgan porphyry Cu-Au deposit, Central Kazakhstan. Ore Geology Reviews. 2024, 174. https://doi.org/10.1016/j.oregeorev.2024.106293

[17] Shen P, Pan H, Seitmuratova E, Jakupova S. U-Pb zircon, geochemical and Sr-Nd-Hf-O isotopic constraints on age and origin of the ore-bearing intrusions from the Nurkazgan porphyry Cu-Au deposit in Kazakhstan. Journal of Asian Earth Sciences. 2016, 116. https://doi.org/10.1016/j.jseaes.2015.11.018

[18] Bouzari F, Hart CJR., Bissig T, Barker S. Hydrothermal alteration revealed by apatite luminescence and chemistry: a potential indicator mineral for exploring covered porphyry copper deposits. Economic Geology. 2016; 111:1397-1410. https://doi.org/0361-0128/16/4423/1397-14

[19] Mishin LF. Eu Geochemistry in Magmatic Rocks of Continental Marginal Volcanic Belts. Geochemistry International. 2010; 48(6):580-592. https://doi.org/10.1134/S0016702910060054

[20] Tatnell L, Anenburg M, Loucks R. Porphyry Copper Deposit Formation: Identifying Garnet and Amphibole Fractionation With REE Pattern Curvature Modeling. Geophysical Research Letters. 2023; 50(14):1-10. https://doi.org/10.1029/2023GL103525

[21] Tosdal RM, DillesJH, Cooke DR. From source to sinks in auriferous magmatic-hydrothermal porphyry and epithermal deposits. Elements. 2009; 5:289-295. https://doi.org/10.2113/gselements.5.5.289

[22] Seedorf E, Dilles JH, Proffett JM, Einaudi MT, Zurcher L, Stavast WJA, Johnson DA, Barton MD. Porphyry Deposits: Characteristics and Origin of Hypogene Features. Economic Geology 100th Anniversary. 2005; 1905-2005:251-298. https://doi.org/10.5382/AV100.10

[23] Vodyanitskii YN. Geochemical Fractionation of Lanthanides in Soils and Rocks: A Review of Publications. EurasianSoil Science. 2012; 45(1):56-67. https://doi.org/10.1134/S1064229312010164

[24] Wu C, Wang C, Hong T, Xu X, Zheng X, Liang W, Sun K, Zhang H, Dong L, Wang B. Constraints on the Formation of the Shiwu Porphyry Cu–Au Deposit in West Junggar, NW China: Insights from Tourmaline-Rich Igneous Rocks. Minerals. 2023; 13:612. https://doi.org/10.3390/min13050612