ABSTRACT

of the dissertation for the scientific degree of Doctor of Philosophy (PhD) in specialty 6D070600 - "Geology and Exploration mineral deposits"

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STUDY OF THE REGULARITIES OF THE DISTRIBUTION OF RARE ELEMENTS (Be, W, Mo) IN THE ROCKS OF CENTRAL KAZAKHSTAN

The presented dissertation work is devoted to the problems of geochemistry of rare elements and their laws of distribution in rocks of Central Kazakhstan, as well as the development of methods for forecasting rare metal deposits.

Relevance of the work. One of the main tasks of geological research is the expansion of the country's mineral resource base, including rare-metal deposits (Be, Mo, W, etc.). Restoring the competitiveness of rare-metal deposits is the most important strategic task; in this connection, the development of the Syrymbet deposit has begun, and a number of other deposits are being reviewed and re-evaluated. Under these new conditions, scientific interest in the geochemistry and metallogeny of rare elements is reviving. Reliable data on the distribution of rare elements Be, W, Mo in the rocks of Central Kazakhstan will make it possible, first of all, to study in detail the patterns of distribution of rare-metal deposits, of which there are about a hundred in the region, including unique reserves.

First President of the Republic of Kazakhstan N.A. In his message to the people of Kazakhstan (dated January 31, 2017), Nazarbayev “The Third Modernization of Kazakhstan: Global Competitiveness” sets new major challenges for geology in the field of forecasting methods and prospecting for mineral deposits. One of the ways to improve the efficiency of exploration is the development of geochemical criteria and search features. The Ministry of ecology, Geology and natural resources of the Republic of Kazakhstan has prepared and published the concept of the State program of geological exploration for 2021-2025, which aims to create conditions for sustainable replenishment, development and support of the competitiveness of the mineral resource base. The main objectives of the state Program are:

- ensuring the geological study of the territory of Kazakhstan;
- replenishment of the mineral resource base (increase in mineral reserves);
- scientific and research support for the geological study of the subsurface;
- automation and digitalization of the geological industry.

In this aspect, the territory of Central Kazakhstan is a large object for studying and carrying out various works aimed at finding new deposits.

The goal of the research is to analyze the current state of geochemistry of Be, Mo, W for developing a method for predicting rare-metal deposits using the most massive search features – lithochemical anomalies.

Ideological and methodical novelty, scientific significance.

At the time of the research, there was actually only one method for identifying the ore nature of lithochemical halos - their direct mining and geological

assessment. It still remains the most reliable, but very expensive and time consuming, despite the fact that thousands of lithochemical anomalies are still waiting for their assessment. The developed method for forecasting rare-metal deposits allows, at relatively low costs and in a short time, to involve all known primary and secondary geochemical halos in the verification using the developed geochemical maps - maps in absolute contents and geochemical maps of the new type - the map in the clarke-concentration isolines.

Objectives of the study:

- to establish regularities of distribution of Be, Mo and W clarks in geological formations in order to identify geochemically specialized, potentially ore-bearing clarks among them;
- to study the influence of various geological factors and determine the distribution of Be, Mo and W in the rocks of Central Kazakhstan;
- develop a method for constructing geochemical maps of a new type – clarke isolines-concentrations;
- to develop a methodology for evaluating the potentially ore-free and ore-free nature of lithochemical anomalies and on its basis to identify the most promising areas.

Scientific novelty.

1. The regularities of the distribution of Be, Mo, W depending on the composition of rocks in Central Kazakhstan, characterized by correlations with petrogenic components, which made it possible to identify geochemically specialized, potentially ore-bearing rocks.
2. The method of constructing geochemical maps of a new type – maps of clarke isolines-concentrations of elements in rocks, which allows you to deepen research in the field of Geochemistry of geological processes of rock and ore formation, geochemical zoning of the territory and determining the geochemical specialization of the vast majority of geological bodies in the region.
3. Method for dividing lithochemical anomalies into potentially ore-bearing and ore-free anomalies, which allows us to recommend ore anomalies for the law of geological exploration for the detection of industrial-type ore occurrences.

Practical significance. The method of screening lithochemical anomalies for potentially ore and barren will be used to conduct search and prospecting for rare-metal deposits in Central Kazakhstan. For the first time, the expediency of using regional clarks for individual elements, in particular for Be, is justified, the discrepancies of which in regional and world clarks average 2-3 g / t, the clarke Mo and W of Central Kazakhstan exceed the values of world clarks, which makes it possible to divide in more detail and highlight lithochemical anomalies on these elements.

The final result of the research is the established patterns of distribution of elements (Be, Mo, W) in the rocks of Central Kazakhstan and their assessment of statistics; the results of the approved method for forecasting rare-metal deposits, which are shown on sheet M-43-A, covering a part of the territory of Central Kazakhstan.

Unchecked lithochemical halos, zones of mainly elevated metal contents in the soils, were used as the base of the main search features in the work. There are thousands of such halos in the region, but not all of them are of the ore nature. The main tool for screening lithochemical anomalies for promising in relation to the detection of mineralization and barren are geochemical maps of bedrock and, first of all, the developed geochemical map of a new type - the map in the clarine isoline concentrations, which was first created in Central Kazakhstan according to the research. In the end, the world geochemical practice was the first to create a system of regional breed clarks of a large region, based on the results of studies of 15,000 composite samples prepared from 400,000 primary samples for 168 species of bedrock (IV Glukhan and V.I. Serykh. 2003).

According to the M-43-A sheet, 5 forecast areas of promising potential for the possible discovery of rare metal deposits are allocated. Promising areas include areas within which there is at least one positive predictive feature: the geochemical field (geochemical features) of both soils and bedrock, geological and structural features favor the manifestation of mineralization. On this sheet, a forecast is made only for rare elements (Be, Mo, W), which are the subject of research in this dissertation, so the study for the presence of anomalies of other metals was not carried out. It is recommended to continue research on anomalies of other elements for their prediction.

In the process of generalizing the extensive factual material and its careful analysis, a lot of conclusions of various levels and significance were obtained. In the present conclusion made the most important conclusions:

Molybdenum. Studies have found that the vast majority of specific types of rocks of Central Kazakhstan are characterized by elevated levels of this element compared to the clarks of the earth's crust. From this it follows that Central Kazakhstan is a molybdenum province. Based on this, the permanent presence of Mo in most of the industrial ore deposits of the region becomes logical and understandable: Bozshchakol, Nurkazgan, Konyrat, pyrite with polymetals - Maykain, Kosmuryn (southeast branch of the Devonian belt in Ordovician); rare metals: essentially tungsten - Upper Kairakty, Baynazar, South Zhaur, Akchatau; complex - Koktenkol, Karaoba; molybdenum proper - Eastern Konyrat, Shalgiya, Karatas-4; essentially beryllium - Nurataldi, Northern Konyrat; Paleozoic uranium deposits Kokchetavshiny; sandy sandstones - Zhezkazgan, Kiyma, Altyntobe; deposits of Sayak group (Sayak-1, etc.).

In the igneous rocks of Central Kazakhstan, Mo is distributed more or less evenly, which is consistent with any correlation (R = 0.2) with SiO_2, the contents of which vary significantly – from 44% to 78%, as well as the type of alkalinity of the rock (potassium), determined by the ratio K_2O/Na_2O at R=0.1, S= 0.18 g/t. Meanwhile, other stronger Mo correlations were established: a) in ultrabasic and basic rocks – with TiO_2 (according to the equation y=0.0229x+1.3115, at R=0.42 $t_{surv}>t_{table}$, with α=0.01 and S=± 0.13 g/t); b) on the level of alkalinity of the medium, determined by the sum of $K_2O + Na_2O$ at R=0.53 $t_{surv}>t_{table}$, with α=0.001); c) from agpaiticity (predominance of alkalis (K+Na) over aluminum) of

rocks, determined by the ratio K_2O+Na_2O/Al_2O_3 at R=0.43 $t_{surv}>t_{table}$, with α=0.001, S=± 0.25 g/t.

In sedimentary rocks, Mo is also fairly uniformly distributed, as evidenced by its low correlation coefficient with SiO_2, R=0.23. With an increase in the total content of $Al_2O_3+Fe_2O_3+FeO+MnO$ in argillite rocks, the Mo content increases due to its adsorption properties, this dependence is described by the equation y=0.0572x+0.527, R=0.41 $t_{surv}>t_{table}$, with α=0.001, S=± 0.2 g/t. With an increase in the type of alkalinity of the rock (K_2O/Na_2O ratio), the Mo content increases, as indicated by the correlation coefficient R=0.48 $t_{surv}>t_{table}$, with α=0.001.

The highest Mo contents are noted in metamorphic rocks, in which it is associated by correlation with SiO_2 at R=0.61 in the equation y=0.0162x+0.7472. At the same time, in metamorphic rocks, there is a correlation due to agpaiticity, determined by the K_2O+Na_2O/Al_2O_3 ratio with R=0.66. There is also a weak correlation with ∑FeO in meta-sedimentary rocks (according to statistics, at R=0.42 $t_{surv}>t_{table}$, with α=0.03 and S=± 0.13g/t). The level and type of alkalinity can be traced very weak correlations with R=0.21 and 0.13, respectively.

Beryllium. It has been established that the average content of the beryllium lithophilic element increases from ultrabasic (0.4 g/t) to ultra acid (5.2 g/t), in which the SiO_2 content increases. This pattern is described by the equation y = 0.04x-0.99 at R=0.77 $t_{surv}>t_{table}$, with α=0.001, S=± 0.3 g/t, which reflects changes in the concentration of Be containing minerals of these rocks ranged by SiO_2, it should be noted that there is no isomorphic bond between Be and SiO_2 in minerals these breeds.

The most significant relationship between Be and F, described by the equation y=0.0048x-0.5725, is due to the covalent bond of these two elements in the differentiation of the magmatic melt that occurs at high temperatures. This bond is known in the form of several modifications of the structure similar to the modification of dioxysilicon.

In alkaline rocks, the established relationship between Be and Al is described by the equation y=0.112x1.36, with the correlation coefficient R=0.92, which is explained by their isomorphic relationship.

Among the sedimentary rocks, two main groups of rocks are distinguished, differing in the content of Be - chemogenic sediments and terrigenous. In the first group, the Be content is reduced, since they do not contain minerals concentrating and bearing minerals Be, and terrigenous sediments are the result of mechanical destruction of mainly igneous rocks, and in them vary to some extent all the patterns characteristic of igneous rocks . This pattern is described by the equation y = 0.0167x + 0.0101, where x is SiO_2, y is the content of Be.

It has been established that all potassium varieties of rocks are richer in beryllium as compared with the sodium and calinatra varieties of rocks with the same content of SiO_2. This is confirmed by the correlation dependences with R=0.73 for igneous rocks, R=0.69 for sedimentary rocks and R=0.92 for metamorphic rocks.

In metamorphic rocks, the regularities of the Be distribution are the same as in the original rocks, since, which indicates that regional metamorphism is realized in them in isochemical conditions.

Tungsten. A number of regularities of the distribution of W of them are established:

1) the average tungsten content in igneous rocks increases from ultrabasic rocks (0.1–0.8 g/t) to basic and intermediate rocks (1.0 g/t) and further to acidic (1.5–2.0 g/t) and ultra-acid (2.2 g/t) in which the clarke of tungsten is highest. This pattern is described by the equation $y=0.34x+0.24$ with a correlation coefficient $R=0.90$ $t_{surv}>t_{table}$, with $\alpha=0.001$.

2) tungsten accumulates in acidic and ultra-acid (leucogranite alaskites, leucogranites) igneous rocks. The abnormally high tungsten content in these rocks indicates the effect on them of post-magmatic processes: muscovitization, greisenization.

Among sedimentary rocks, the lowest average tungsten content is typical for carbonate rocks (1.2 g/t), in which there are no tungsten carrier minerals, and in clay rocks it is 2 times higher - 2.6 g/t, which indicates the presence of minerals of the element in these rocks, which is caused by the products of destruction of acid and ultra-acidic igneous rocks.

It is recommended to use geochemical maps for the bedrocks of the area — maps in the isolines of the contents and a geochemical map of a new type (maps in the isolines of the clarke concentrations). These maps make it possible to divide untested lithochemical halos into potentially ore-bearing and barren ones using the above method.

Personal contribution of the author. Consisted in the collection, processing, systematization, synthesis and interpretation of factual material; in conducting field work with sampling for further analytical studies; in justifying the relevance of research work; in the study of the geochemistry of rare elements; in establishing patterns of distribution of elements in rocks; the development of methods for forecasting rare metal deposits based on a joint analysis of lithochemical anomalies, geochemical maps in isolines and clarke concentrations, as well as drawing up a forecast map on sheet M-43-A.

Protected scientific position.

1. Central Kazakhstan is essentially a molybdenum province. The vast majority of rock types in Central Kazakhstan are characterized by high Mo content compared to the earth's crust Clarke.

2. Regularities of the distribution of Ve, Mo and W in the rocks of Central Kazakhstan, which allowed us to identify geochemically specialized, potentially ore-bearing rocks: quartz sienites sub-alkaline potassium, alkaline quartz sienites K-Na, subgranites, leucogranites, alkaline feldspar leucogranites, Alaskan leucogranites, alkaline alaskanites.

3. Method of sorting lithochemical anomalies into potentially ore-bearing and ore-free ones based on geochemical criteria and geochemical maps in the isolines of contents and Clarke concentrations.

Approbation. The main provisions of the dissertation work were presented: at the III international conference "Earth Sciences: yesterday, today, tomorrow" (Saint Petersburg, 2017); at the XXII international Symposium named after academician M. A. Usov of students and young scientists (Tomsk, 2018, 2019); at the XXXV International conference "earth Magmatism and related deposits of strategic metals" (Moscow, 2018); at the International scientific conference "Current scientific research in the modern world" (Pereyaslav-Khmelnitsky, 2018); at the international scientific and practical conferences "Saginovs readings" (Karaganda 2017, 2018); at the Republican student scientific conference "Contribution of youth science to the implementation of the Strategy "Kazakhstan-2050" (Karaganda 2019); at the international scientific and practical conference "Bekzhanovs readings" (Almaty 2019).

In the period from April 7 to April 21, 2018, a scientific internship was held at CERCAMS, Museum of Natural History, Department of Earth Science in London, United Kingdom, under the guidance of a senior researcher, PhD Ph.D. Dolgopolova A.V. During the time of the scientific internship, she participated in the scientific seminar of the leading scientists of the Museum of Natural History. Received certificate of successful completion of a scientific internship.

The main provisions of the dissertation work were published in 16 scientific works, 4 of which, in publications recommended by the Committee on the Control of Education and Science of the MES RK, 9 in the works of Kazakhstan and foreign international conferences and 3 articles included in the Scopus and Clarivate Analitics database.

The research results are introduced into the educational process for conducting lectures and practical classes on the discipline "Integrating modern methods of forecasting and prospecting for deposits" at the Department of Geology and Mining, EKSTU. Serikbayev. At the same time, the results of the work have been implemented in the practice of MD "Centerkaznedra" and LLP "GeoTec".

Structure and scope of the dissertation. The dissertation is presented on 164 pages of computer set and consists of an introduction, six chapters, conclusion and a list of sources used, including 286 titles. The dissertation is illustrated with 62 figures and 19 tables.

Gratitudes. This work was carried out thanks to the recommendations of scientific consultants: doctor of geology Serykh Vyacheslav Ivanovich, head of the Department "Geology and exploration of minerals deposits" Portnov Vasily Sergeyevich, to whom the author expresses deep appreciation for the productive advice and guidance on the dissertation. The author expresses gratitude to foreign consultant – Dr. PhD, senior researcher of the scientific center CERCAMS, Natural history Museum Dolgopolova Alla Vladimirovna for her consultation and valuable advice during the work on the dissertation and internship. In addition, the author thanks Professor, PhD, Director of CERCAMS Raimar Zeltman for organizing and passing a scientific internship, for advice, ideas and recommendations in conducting research.