UDC 556.114

https://doi.org/10.33271/nvngu/2021-5/016

B. B. Amralinova[1],
orcid.org/0000-0003-0716-5265,
O. V. Frolova[1],
orcid.org/0000-0001-9144-6291,
I. E. Mataibaeva[1],
orcid.org/0000-0003-0550-7591,
B. B. Agaliyeva[1],
orcid.org/0000-0002-5682-8451,
S. V. Khromykh[2],
orcid.org/0000-0001-5951-0660

1 – D. Serikbayev East Kazakhstan Technical University, UstKamenogorsk, the Republic of Kazakhstan, e-mail: bakytzhan_80@mail.ru
2 – Novosibirsk National Research State University, Novosibirsk, Russian Federation

MINERALIZATION OF RARE METALS IN THE LAKES OF EAST KAZAKHSTAN

Purpose. Study on the chemical composition of lake waters, salt brines, brine and bottom sediments to identify the mineralization of rare metals and other types of minerals.

Methodology. Mass spectrometric studies (mass spectrometer with inductively coupled plasma ICP-MS 7500cx from Agilent-Technologies) for the purpose of high-precision analytical studies on the chemical composition of salt lake water in order to assess the content of rare elements. The use of unmanned aerial vehicles for linking and geometrizing lakes.

Findings. Field surveys on the geometrization and linking of lakes were carried out. From the materials obtained with the help of the drone, orthophotoplans were created (with a measurement accuracy of up to 1 centimeter), as well as a digital terrain model and a digital terrain model. A complex of analytical works was carried out using inductively coupled plasma spectrometry. When analyzing the distribution graphs of the absolute content of micro-components in the waters of the lakes of the Delbegeteysky massif, it was found that all samples were enriched with sodium, phosphorus, iron, magnesium and barium. The results of the analyses revealed the predominance of sulfates and chlorides in the composition of the surface waters of most of the water bodies of the Delbegeteysky massif. At the Burabai site, lake waters are characterized by an alkaline reaction of the environment (on average pH = 8.71). At the same time, the salinity of water bodies varies from 05 to 9 g/dm^3.

Originality. Large-scale outcrops of granites of the Kalba complex (P1), with which a rare-metal type of mineralization is genetically associated, are known to be on the selected study sites. Quartz-wire-greisen and quartz-wire tin, tin-tungsten and tungsten formations are also widely developed. Considering the large geochemical migration ability of rare alkaline elements in the thickness of loose sediments as a result of intensive geodynamic processes in the East Kazakhstan region, it is possible to assume the possibility of their migration to the upper horizons and accumulation in salt lakes localized within the area of development of granite intrusions of Permian age and associated deep tectonic faults.

Practical value. The results of the research can serve as a revival of the rare metal industry in the region, which will allow developing new high-tech industries and creating new jobs in this area. The obtained results can be used for setting up further exploration and operational work on the selected promising areas.

Keywords: *hydrogeochemistry, rare metals, lake waters, mineralization, granite intrusions*

Introduction. Currently, Kazakhstan is facing an acute problem of recreating its own mineral resource base of rare metals (Ta, Nb, Be, Li, TR, and so on) [1, 2].

At present, the problem of providing existing enterprises with raw materials is particularly acute in the East Kazakhstan region. In connection with the current situation, a necessary condition for getting out of the current state and further favorable development is to increase the efficiency of prospecting and exploration works based on metallogenic research using new modern technologies and methods to assess the prospects of both Kazakhstan as a whole and its individual regions for the discovery of new deposits [3].

The most important task is to improve the criteria for forecasting and searching for new deposits. In the process of research work, much attention was paid to the development of geological-structural, ore-petrological and mineral-geochemical criteria for forecasting and searching for the leading types of deposits of rare metals and rare earths [4].

Rare metals are the metals behind which the future of the modern world stands. The revolution in the field of science and technology, which covers all spheres of life, is associated, first, with the widespread use of rare metals. Their use has contributed to the revival of many areas of modern industry, science and technology. All high-tech structural materials are currently created using rare elements. Rare elements are an integral part of all resources- and energy-saving technologies. Rare metals are used quite effectively in various areas of the military and civil industry. Compounds of lithium, uranium, boron, bromine, etc. are used for the production of modern materials that are used in electrochemical and nuclear energy, chemistry and materials science. To obtain such compounds, solid raw materials are usually used. However, since the end of the *20th* century, unconventional raw materials, including hydromineral resources of salt lakes, have been increasingly used for these purposes. Salt lakes in different regions of the world have been used for a long time for the production of some important chemical products; the traditional ones are sodium chloride, sodium sulfate and sodium carbonate. At the end of the twentieth century, lithium, boron and bromine compounds began to be extracted on an industrial scale from the salt lakes of South America and China [5]. The demand for lithium has increased significantly in the last ten years, which is mainly due to the use of lithium in power supply batteries for laptops, mobile phones and other electronic devices [6]. The global economic situation is such that the consumption of metals of this group by industry increases every year, but production does not, i.e. demand exceeds supply and, in some cases, by many times [5]. Many scientists have made a huge contribution to the study on rare metal mineralization of Kazakhstan. M. A. Abdulkabirova, Zh. A. Aitaliev, N. T. Bakulin, G. I. Bedrov, G. R. Bekzhanov, P. A. Belykh, E. D. Belyakova, and others participated in the research. In the fifties, numerous reports on rare metals and mineral complexes with forecasts and recommendations appeared (D. G. Azhgirey, Zh. A. Aitaliev, G. I. Bedrov, G. R. Bekzhanov, Ya. V. Belyaeva, E. D. Belyakova, V. G. Bogolepov, V. E. Bocharov, A. N. Butaets, A. R. Butko, A. V. Bogdanova, V. I. Volobuev, V. I. Galchenko, F. G. Gubaidulin). We should note the works by A. Abeuov, N. H. Adamyan, S. L. Avdeev, E. V. Alperovich, G. R. Bekzhanov, etc.

The purpose of the work is to scientifically substantiate the prospects for detecting the mineralization of rare metals and other types of minerals in the lakes of Eastern Kazakhstan and to develop recommendations on the possibility of developing and using lake waters and salt brines for the production of alkali metals. The industrial concentration of many rare metal elements in salt marshes and in the brine of lakes allows us to consider them as an additional (and for some elements, the main) source of mineral raw materials. A number of rare elements from evaporites are already being extracted abroad in many countries [5]. For example, the largest producers of lithium carbonate (82 % of world production) are SQM (Sociedad Química y Minera de Chile), Chemetall and FMC Lithium, which produce lithium from lakes in Argentina and Chile, and Talison Minerals, which develops lithium mineral deposits in Australia. Their main competitor is China (Lake Chabier-Tsaka), which implements both public and private investments in lithium mining technology. In 2007, Uzbekistan for the first time invited foreign companies to cooperate in the development of rare earth metals. For potential investment, Goskomgeo proposed conducting risk-based geological exploration for rare metals at twelve promising areas in Western and Southern Uzbekistan, followed by the submission of exclusive development rights. Over the past ten years, research has been carried out on salt lakes on the territory of Western Mongolia [6] and many regions of Russia [5] on this topic. The technology of lithium extraction from brines of a number of salt lakes in recent years has been winning over quarry mining from polymetallic ores, both in terms of profitability and product quality. According to experts, despite the lower content of this metal or problems with the purification of related elements (magnesium), this type of mining gives a more stable composition of raw materials and a more productive technology.

In particular, the American company Simbol Materials decided to use a method of lithium extraction, which not only allows reducing its price, but also opens up new deposits of this metal [6]. Simbol Materials is going to extract lithium from a natural solution raised from the depth of highly saline lakes due to geothermal stations, which allows reducing energy consumption during production. Using its own resources, this technology raises the solution for processing, simultaneously receiving heat and purified water. If it is possible to develop several geothermal stations at once, then by 2020 Simbol Materials alone will be able to meet a fifth of the world's lithium needs. The studies were carried out within the Burabaysky and Delbegeteysky sites.

Delbegeteysky site. This site is located in the West Kalba metallogenic zone, including endo-and exocontact zones of the granite massif of the same name, which is part of the Semipalatinsk-Buran-Burgyn granitoid belt of the north-western direction. The site is characterized by the development of greisen and quartz-vein tin deposits (Kyzylzhar, Sherlovaya, Arkad, and others), as well as tin ore occurrences of increased sulfidity (such as mineralized zones) superimposed on the dikes of the Kunush complex (Jubilee October). Ancient miners developed these deposits, and in modern times the prospecting artel was developing the Emerald ore occurrence. In tectonic terms, the Delbegeteysky massif is located at the intersection of latitudinal, meridional and northwestern deep faults, the activation of which is associated with the repeated introduction of granite melts and metasomatic transformations of granites and rocks in the superintrusive zone (Fig. 1) [7].

The geological structure is associated with terrigenous deposits of the Aganakta (C1s) and Bukon (C2-3) formations,

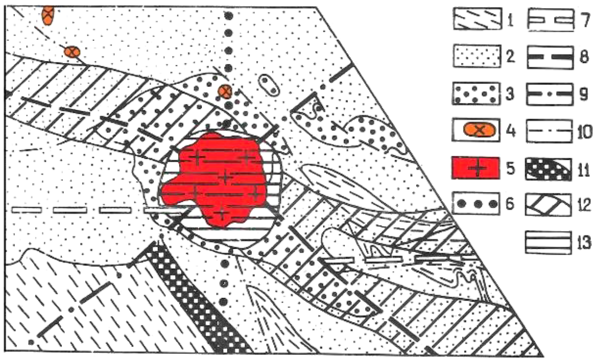

Fig. 1. Geological and structural position of the Delbegetey tin ore node:

1–5 – geological formations (1 – carbonate – terrigenous, Arkalyk formation, C1v2-3; 2 – graywacke silt – sandstone, Aganakta formation, C1s; 3 – conglomerate – sandstone molasse, Bukon formation, C2-3; 4 – small intrusions of plagiogranite – granodiorite formation, Kunush complex, C3; 5– granite – leucogranite, Delbegetey complex, P2); 6 – 9-deep faults (6–7 – orthogonal longitude – latitude, 8–9 – longitudinal – transverse); 10 – small breaks; 11–13 – ore-bearing structures (11 – fragments of the Char chromium-cobalt-nickel-mercury zone, 12 – the West Kalba gold-sulfide zone, 13 – the tin ore node) [7]

overlain by a cover of loose sediments of the Neogene and Quaternary systems. Intrusive formations are represented by gabbro-diabase dikes of the Argimbai complex (C2-3), small intrusions and dikes of the Kunush complex (C3), and granitoids of the Delbegeteysky complex (P2). Of fundamental importance is geological evidence of an earlier Upper Carboniferous (pre-granite) age of the porphyry dikes of the Kunush complex, which cut through the sedimentary strata of the Bukon Formation (C2), and themselves are cut off and metamorphosed by granites of the Delbegeteysky massif overlapping with the Oktyabr sulfide-cassiterite mineralization (Yubyr). At the same time, these dikes and their thin apophyses intersect gabbro-diabases of the Argimbai complex (C2-3) [7].

The main feature of the geological structure of the Delbegeteysky massif is that there are three intrusive phases with their own ore content: 1) granosyenite (mineralization is not manifested); 2) granite (Sn, Be); 3) leucogranite (Sn). The constructed geological-genetic model reflects the vertical zoning of the manifestation of metasomatic processes and mineralization in the filtering column, the successive change in ore formations and mineral types of tin ores (Fig. 2) [7].

The granosienite phase belongs to the sub-alkaline group of rocks by the nature of alkalinity and is comparable in material composition to the Buran complex, geochemically specialized for Ti, Zr [5].

Geochemically, the clarke concentrations of Pb (by 7.4 times), Sn (by 2.7 times), Mo, Li, Nb, Yb (by 2–3 times) were increased in miarol granites, and high fluorine contents were found in the micas of their miarol nests and tin – bearing greisens [7].

Burabaysky site. The geological structure of this site involves Upper Devonian-Lower carboniferous deposits, which are broken through by granites and Quaternary sediments of various ages and genesis. The section is dominated by sandstones, shales; they are covered by modern Quaternary alluvial deposits, represented by gravel-pebbles with a sandy aggregate. Fissured waters are developed on the right – left bank of the river. Kurchum and are confined to the fractured zone of effusive-sedimentary rocks. The thickness of the zone varies from 20 to 60 m, the water content of the rocks is low. Due to the remoteness of distribution and low water availability, Burabai villages have no practical interest in water supply. The valley of the Kurchum River is characterized by a wide area development of the alluvial aquifer of modern age, which has high fil-

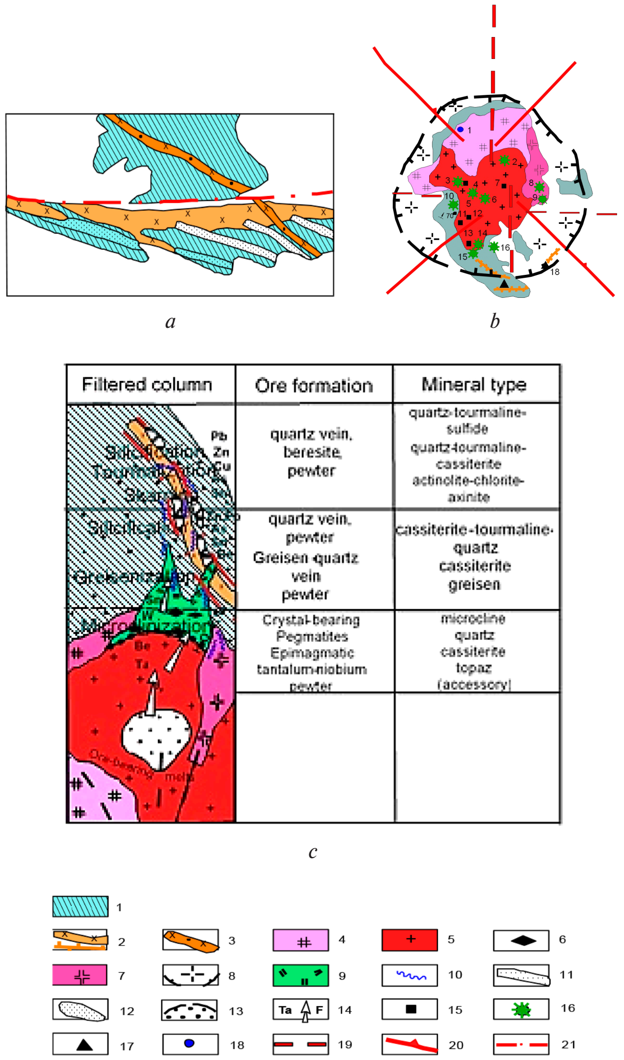

Fig. 2. Geological structure of the Delbegeteysky ore node:

a — geological scheme-plan; b — geological scheme of the Yubileyny Oktyabr deposit; c — scheme of the zonal ore column. 1 — conglomerate-sandstone deposits of the Bukon formation, C2; 2–3 — Kunush complex, C3: 2 — granite-porphyry, quartz porphyry; 3 — granodiorite-porphyry; 4 — 8 — Delbegetey complex, P1; 4 — monzonites, granosyenites of the I phase; 5 — medium-grained porphyritic; 6 — miarol granites of the II phase; 7 — leucogranites of the III phase; 5 — contour granite massif at a depth (according to geophysical data); 9 — greisenization; 10 — bearing quartz veins and veinlets; 11 — scarring; 12 — zones of sulfide — cassiterite mineralization; 13 — emanation halo of ore — bearing intrusion; 14 — direction of movement of ore-bearing elements; 15–18 — manifestations: 15 — greisen quartz — vein; 16 — quartz-vein; 17 — sulfide and 18 — polymetallic; 19 — deep faults according to geological and geophysical data Caledonian and 20 — Hercynian; 21 — small breaks [7]

tration properties and water availability. The water-bearing sediments are represented by boulder-pebbles with a sandy aggregate. The thickness of the deposits varies from 4 to 30 m or more. Upper Devonian-Lower Carboniferous sandstones underlie the horizon. In the course of analysis and generalization of literature and archival data, it was found that groundwater has a free level, whose depth varies from 1.55 to 2.55 m. The water content of the horizon is high, the flow rates of wells vary from 18.8 to 27.7 dm/s with a decrease of 3.1–0.8 m (in the area of the village of Kurchum) to 5 dm/s with a decrease (in the area of the village of Burabay). The flow rates in the pits in the spring reach 8–9, in the summer 5–b dm/s. According to the detailed survey of underground waters for the village of Kurchum, the water regime is closely related to the regime of surface waters, the hydraulic connection between them is very close. The amplitude of the level fluctuations reaches 1.2 m in the immediate vicinity of the river and decreases to 0.4–0.7 m at a distance from it. The main source of power for the horizon is the surface waters of the Kurchum River, unloading is carried out in the lower horizons [8].

On the described area, the role of hosts for the Kalba-Narym pluton is played by the sediments of the Burabay formation. The study on sediments of the Buribay formation is complicated by the variety of lithological composition, isoclinal and disharmonic folding, the absence of marking horizons and faunal remains. In addition, along the boundaries of the Kalba-Narym pluton, the rocks of the formation are intensively keratinized.

The Burabay Formation is characterized by uneven intercalation of gray medium- and fine-grained quartz-feldspar, polymictic, sometimes initially weakly calcareous and black carbonaceous-argillaceous siltstones. Sandstones are sharply dominated in the lower part of the formation, and siltstones in the upper part.

Geometrization of lakes. The sampling points were referenced using a GPS navigator, as well as with the help of a special software application for an Android smartphone – Field-Move Clino. Further, all sampling points were entered on Google Earth satellite images, and monitoring and referencing were carried out using the Sentinel-2 Earth remote sensing satellites. In addition, to depict the structural features of the lakes in the studied areas, to assess their geometry, aerial photography was carried out using a UAV (unmanned aerial vehicle).

Aerial photography was carried out by a DJI Mavic quadcopter in automatic mode with the preparation of a flight task in the Pix4Dcapture program. After receiving the initial data in the form of georeferenced aerial photographs, a digital elevation model was created using the Agisoft PhotoScan program (Fig. 3).

Then a height map is created. And in conclusion, an orthophotoplan and a digital model of the terrain are built.

With the help of the obtained results, in the office conditions, it is possible to make any measurements, for example, the area and volume of the object being examined.

Geochemistry of surface waters of lakes in the studied areas. *Delbegeteysky site.* According to the results of the expedition studies, the hydrochemical composition was determined by more than 20 main indicators, including: pH, mineralization, content of potassium, sodium, magnesium, ammonium ions, nitrites, nitrates, phosphates, silicon, aluminum, copper, iron, lead, zinc, nickel, cadmium, manganese and rare metals (Fig. 4) [7, 9].

The distribution curves of microcomponents on a logarithmic scale show a generally synchronous change in the content of microcomponents in lakes. When analyzing the graphs of the distribution of the absolute content of microcomponents, it was found that all samples are enriched with sodium, calcium, manganese, iron, magnesium and barium. As a result of the studies carried out, it was found that, in general, the

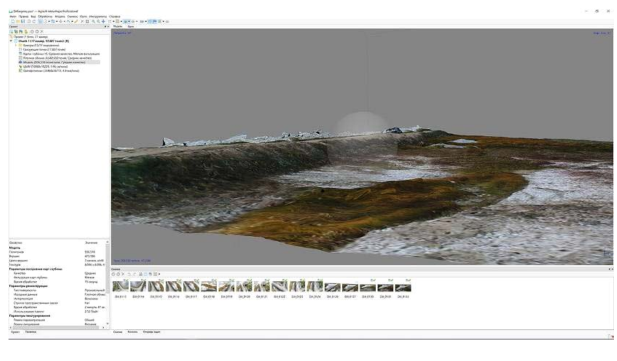

Fig. 3. Digital elevation model

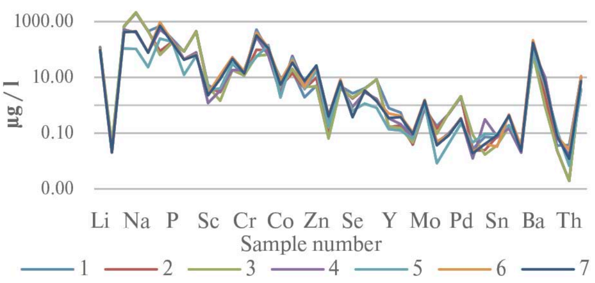

Fig. 4. The content of micro-components of the lakes of the Delbegeteysky massif

hydrochemical composition of lake waters 1–3 does not have significant differences and according to the classification of O.A. Alekina belong to the sulfate class, sodium group of the second type [10]

$$\text{II. } HCO_3^- < Ca^{2+} + Mg^{2+} < HCO_3^- + SO_4^{2-}$$

Type II waters are mixed. Their composition can be genetically related to both sedimentary rocks and weathering products of igneous rocks. This type includes the water of most rivers, lakes and groundwater with low and moderate mineralization [8].

The hydrochemical composition of lake waters 4–7 differ significantly and according to the classification of O.A. Alekin [10] belong to the bicarbonate class, the calcium groups of the first type [7]

$$\text{I. } HCO_3^- > Ca^{2+} + Mg^{2+}$$

Type I waters are formed as a result of chemical leaching of igneous rocks or during the exchange of calcium and magnesium ions for sodium ion. Most often they are poorly mineralized, except for the water of drainless lakes [7].

In addition, lake waters are characterized by an acidic reaction of the environment (on average, pH = 3.9).

At the same time, in most of the surveyed objects, according to the indicator "total hardness", the surface waters of objects 1–3 belong to the category of very hard water (more than 12 mg-eq/l), and the waters of objects 4–7 belong to the category of medium hardness (4–8 mg-eq/l). The heterogeneity of surface waters by anionic composition and their belonging to the bicarbonate and chloride classes has been established. According to the research results, the predominance of sulfates and chlorides in the composition of surface waters of most water bodies was revealed [7].

According to the results of the analytical studies, it was also found that the concentrations of sodium ions are in the range from 0.05 to 2.5 g/dm^3.

Clay-sand deposits accumulate at the bottom of the lakes, which are mainly products of coastal erosion. At the same time, a significant part of the bottom sediments are autigenic minerals that fall out of lake waters supersaturated with salts. Lake baths are filled with precipitation, so that lakes have insignificant depths [11].

Many researchers assume that salinization of these lakes is the result of deterioration of the groundwater regime [12].

Burabaysky site. In the course of the research, 15 lakes were identified in the study area, taken as a basis for studying the content and changes in key parameters and components that determine the geochemical appearance of the research area. In the study area, the formation of the hydrochemical composition of surface waters occurs under the influence of natural and climatic conditions.

A number of features of the lakes of this area should be noted. Waterlogged catchments contribute to the accumulation of a wide range of organic substances in surface waters – products of incomplete destruction of plant litter. In turn, the presence of intermediate decomposition products of plant biomass in natural waters determines the slightly acidic reaction of the medium, which favors an increase in the mobility of a number of metals in the composition of organomineral complexes.

The result of this may be an excess in water bodies of the maximum permissible concentrations (MPC) established for the waters of fisheries and drinking water bodies, including iron, aluminum, manganese, copper, zinc and rare metals. During the expedition studies, the hydrochemical composition was determined by more than 20 main indicators, including: pH, mineralization, content of potassium, sodium, magnesium, ammonium ions, nitrites, nitrates, phosphates, silicon, aluminum, copper, iron, lead, zinc, nickel, cadmium, manganese and rare metals (Fig. 5) [8, 10].

The distribution curves of micro-components on a logarithmic scale show a generally synchronous change in the content of micro-components in lakes. When analyzing the distribution graphs of the absolute content of micro-components, it was found that all samples were enriched with sodium, phosphorus, iron, magnesium and barium. As a result of the conducted studies, it was found that, in general, the hydrochemical composition of lake waters 1–10, 13–15 has no significant differences according to the classification of O.A. Alekin [10] belong to the bicarbonate class, the calcium groups of the first type

$$\text{I. } HCO_3^- > Ca^{2+} + Mg^{2+}$$

Type I waters are formed during the chemical leaching of igneous rocks or during the exchange of calcium and magnesium ions for sodium ion. Most often, they are poorly mineralized, with the exception of the waters of drainless lakes.

The waters of the studied lakes according to the classification of O.A. Alekina belong to the hydrocarbonate class, the first type of calcium group.

The hydrochemical composition of lake waters 11 and 12 is also significantly different and according to the classification of O.A. Alekina belong to the sulfate class, sodium groups of the second type

$$\text{II. } HCO_3^- < Ca^{2+} + Mg^{2+} < HCO_3^- + SO_4^{2-}$$

Type II waters are mixed. Their composition can be genetically related to both sedimentary rocks and products of weathering of igneous rocks. This type includes the water of most rivers, lakes and groundwater with low and moderate mineralization.

In addition, lake waters are characterized by an alkaline reaction of the environment (on average, pH = 8.71).

At the same time, the mineralization of water bodies varies from 0.5 to 9 mg/dm^3. At the same time, in most of the surveyed objects, according to the indicator "total hardness", the surface waters of objects 1–5, 8, 9, 13–15 belong to the category of medium hardness (4–8 mg-eq/l), and the waters of objects 6, 7 and 10–12 belong to the category of very hard water (more than 12 mg-eq/l). The heterogeneity of surface waters by anionic composition and their belonging to the bicarbonate

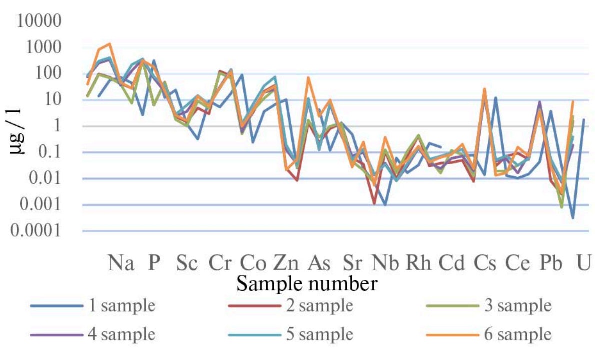

Fig. 5. The content of micro-components of the lakes of the Burabaysky massif

and chloride classes has been established. The results of the conducted studies revealed the predominance of sodium ions in the cationic composition of surface waters of most water bodies (Fig. 6) [8].

The analysis results also showed that the concentration of magnesium ions is in the range from 0.3 to 1.4 g/dm^3, and calcium ions – from 0.2 to 0.5 g/dm^3. Potassium ions are the lowest in the surface waters of the study area (from 0.05 to 1.1 g/dm^3). Territorial differences in the content of cations in waters are weakly expressed.

The study area is confined to the contact of the Burabay Formation deposits with the granodiorites of the first phase of the Kalba complex. Two complex rare-metal anomalies are recorded here: northern (area of about 12 km^2) and southern (area of about 5 km^2). The first is characterized by the contents of niobium 0.0008–0.002 %, bismuth 0.0002–0.0005 %, beryllium 0.0005–0.0008 %, lithium 0.0015–0.002 %, tin 0.001–0.0015 %. The second consists of three local halos of beryllium 0.0005 %, tin 0.001–0.0012 % and lithium 0.002–0.008 %, united by a beryllium halo 0.0003–0.0004 %.

Taking into account the recommendations of the predecessors (Lopatnikov V. V., 1985), a rather significant saturation of the described area with small (albeit low-contrast) halos, as well as the localization within the field of several points of mineralization of tantalite-columbite, cassiterite and beryl (Pridorozhniy site) and the proximity of Cherdoyaksky the tin-tungsten deposit is of undoubted practical interest.

The results obtained during the research on lakes 8–10 show high lithium contents of 366.20 micrograms/l, Orlov 0.047 micrograms/l, which corresponds to the materials of previous studies on the territory for rare metal mineralization [5].

The results of the study on waters do not allow at the present stage answering all questions about the formation of geochemical features unambiguously. The peculiarities of the microcomponent composition of the waters of the Burabay massif lakes give grounds to assume that aureoles, as well as the localization of several points of mineralization of tantalite-columbite, cassiterite, and beryl, are a probable source of rare metals and other micro-components in the waters of the Burabaysky massif lakes [8].

Conclusions. When analyzing the distribution graphs of the absolute content of micro-components in the waters of the lakes of the Delbegeteysky massif, it was found that all samples were enriched with sodium, phosphorus, iron, magnesium and barium. As a result of the conducted studies, it was found that, in general, the hydrochemical composition of lake waters 1–10, 13–15 has no significant differences, the waters belong to the bicarbonate class, the calcium group of the first type. The results of the analyses revealed the predominance of sulfates, chlorides in the surface waters of most water bodies of the Delbegeteysky massif.

At the Burabaysky site, lake waters are characterized by an alkaline reaction of the medium (on average, pH = 8.71). At the same time, the mineralization of water bodies varies from 05 to 9 g/dm^3. At the same time, in most of the surveyed objects, according to the indicator "total hardness", the surface waters of objects 1–5, 8, 9, 13–15 belong to the category of medium hardness (4–8 mg-eq/l), and the waters of objects 6, 7 and 10–12 belong to the category of very hard water (more than 12 mg-eq/l). The waters of the lakes of the Burabaysky massif belong to the bicarbonate and chloride classes. The predominance of sodium ions in the cationic composition of the surface waters of most water bodies in the Burabaysky site was revealed.

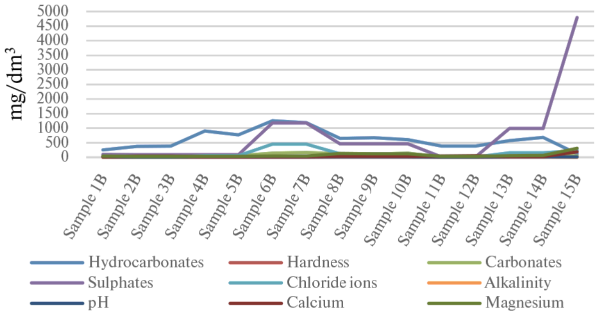

Fig. 6. Composition and physical properties of the lakes of the Burabaysky massif

The results obtained during the research on lakes 8–10 show high lithium content of 366.20 micrograms/l, Orlov 0.047 micrograms/l, which corresponds to the materials of previous studies on the territory for rare metal mineralization.

The results of the water study do not allow us to unambiguously answer all the questions about the formation of geochemical features at the present stage. The peculiarities of the micro-component composition of the waters of the lakes of the Burabay massif suggest that the probable source of rare metals and other micro-components in the waters of the lakes of the Burabay massif are halos, as well as the localization of several points of mineralization of tantalite-columbite, cassiterite and beryl within the studied area.

These results were obtained within the framework of the project AR08052707 "Carrying out hydrochemical studies of the lakes of Eastern Kazakhstan in order to identify in them the mineralization of rare metals".

References.

1. Chanturia, V.A., Chanturia, E.L., Minenko, V.G., & Samusev, A.L. (2017). Enlarged tests of the electrochemical method of water treatment during the enrichment of tantalum-niobium ores. *Ore enrichment*, (3), 27-35. https//doi.org/10.17580/or.2017.03.05.

2. Omirserikov, M.Sh., Stepanenko, N.I., Dyusembayev, K.Sh., & Isaeva, L.D. (2017). Ore-bearing crust of weathering of the rare-earth deposit Kundybai (Northern Kazakhstan). *Mining Journal*, (2), 33-38. https//doi.org/10.17580/gzh.2017.02.06.

3. Smirnov, S. (2011). Rare metals and lands give MMC a rare chance. *Business Journal Kazakhstan*, (3). Retrieved from http://www.invest-kz.com/journals/78/863.html.

4. Dyachkov, B.A., Oitseva, T.A., Frolova, O.V., Mataibayeva, I.E., & Miroshnikova, A.P. (2017). Geological-structural and mineral-geochemical criteria for evaluating rare metal deposits (East Kazakhstan). *Bulletin of D. Serikbayev EKSTU*, (1), 10-20.

5. Makarenko, N.A., & Arkhipov, A.L. (2008). Rare metal potential of salts of the Taloye Ozero tract (Republic of Khakassia). *Bulletin of the Tomsk State University*, (307), 172-1741.

6. Shvartsev, S.L., Kolpakova, M.N., Isupov, V.P., Vladimirov, A.G., & Ariunbileg, S. (2014). Geochemistry and formation of the composition of salt lakes in recorded Mongolia. *Geochemistry*, (5), 432-449.

7. Frolova, O.V., Amralinova, B.B., Agalieva, B.B., Dyachkov, B.A., Mataibayeva, I.E., & Zimanovskaya, N.A. (2020). Features of the geological structure and assessment of prospects of the Delbegeteysky tin ore node (Zapadnaya Kalba). *Bulletin of the D. Serikbayev EKTU*, (3), 36-43.

8. Amralinova, B.B., Akylbaeva, A.T., Agalieva, B.B., Frolova, O.V., & Mataibaeva, I.E. (2020). Geochemistry of surface waters of the Burabay massif lakes. *Bulletin of the East Kazakhstan Technical University named after D. Serikbayev*, (4), 14-17.

9. Geological evolution of the interaction of water with rocks: Proceedings of the third All-Russian scientific conference with international participation on August 20–25, 2018, Chita (2018). Retrieved from http://inrec.sbras.ru/IIIconfWR2018/.

10. Classification of waters by their chemical composition (n.d.) Retrieved from http://abratsev.ru/hydrosphere/classific.html.

11. Karpov, A.V., Vladimirov, A.G., Razvorotneva L.I., Krivonogov S.K., Nikolaeva, I.V., & Moroz, E.N. (2016). Uranium and thorium in bottom sediments of salt lakes of the Ishim steppe (Northern Kazakhstan). *Izvestiya Tomsk Polytechnic University. Georesource engineering*, (9), 6-17.

12. Kolpakova, M.N., Gaskova, O.L., Naymushina, O.S, Karpov, A.V., Vladimirov, A.G., & Krivonogov, S. (2019). Saline lakes of Northern Kazakhstan: Geochemical correlations of elements and controls on their accumulation in water and bottom sediments. *Applied Geochemistry*, (107), 8-18.

Мінералізація рідкісних металів в озерах Східного Казахстану

Б. Б. Амралінова[1], *О. В. Фролова*[1], *І. Є. Матайбаєва*[1], *Б. Б. Агалієва*[1], *С. В. Хромих*[2]

1 – Східно-Казахстанський технічний університет імені Д. Серікбаєва, м. Усть-Каменогорськ, Республіка Казахстан, e-mail: bakytzhan_80@mail.ru

2 – Новосибірський національний дослідницький державний університет, м. Новосибірськ, Російська Федерація

Мета. Вивчення хімічного складу озерних вод, сольових розсолів, ропи й донних відкладень задля виявлення мінералізації рідкісних металів та інших видів корисних копалин.

Методика. Мас-спектрометричні дослідження (мас-спектрометр з індуктивно-зв'язаною плазмою ICP-MS 7500cx фірми «AgilentTechnologies») з метою високоточних аналітичних досліджень за хімічним складом води соляних озер задля оцінки вмісту в них рідкісних елементів. Застосування безпілотних літальних апаратів для прив'язки та геометризації озер.

Результати. Проведені польові дослідження з геометризації та прив›язки озер. З отриманих за допомогою дрона матеріалів були створені ортофотоплани (із точністю вимірів до 1 сантиметра), цифрова модель місцевості та цифрова модель рельєфу. Проведено комплекс аналітичних робіт із застосуванням спектрометрії з індуктивно-зв›язаною плазмою. При аналізі графіків розподілу абсолютного вмісту мікрокомпонентів у водах озер Дельбегетейського масиву було встановлено, що всі проби збагачені натрієм, фосфором, залізом, магнієм і барієм. Результати аналізів виявили переважання сульфатів, хлоридів у складі поверхневих вод більшості водних об›єктів Дельбегетейського масиву. На Бурабайській ділянці озерні води характеризуються лужною реакцією середовища (у середньому pH = 8,71). При цьому мінералізація водних об›єктів варіює від 0,5 до 9 г/дм^3.

Наукова новизна. На виділених ділянках дослідження відомі масштабні виходи на денну поверхню гранітів калбінського комплексу (P1), з якими генетично пов'язаний рідкіснометальний тип зруденіння. Також широко розвинені кварцожильно-грейзенові та кварцожильні олов'яні, олово-вольфрамові й вольфрамові формації. Ураховуючи велику геохімічну міграційну здатність елементів у товщі пухких відкладень у результаті інтенсивних геодинамічних процесів у Східно-казахстанському регіоні, можна припустити можливість їх міграції у верхні горизонти й накопичення в соляних озерах, локалізованих у межах ареалу розвитку гранітних інтрузій пермського віку та пов'язаних із ними глибинних тектонічних розломів.

Практична значимість. Результати досліджень можуть послужити відродженню рідкіснометалевої галузі в регіоні, що дозволить розвивати нові високотехнологічні виробництва та створити нові робочі місця в даній сфері. Отримані результати можуть бути використані для постановки подальших геологорозвідувальних і експлуатаційних робіт на виділених перспективних ділянках.

Ключові слова: *гідрогеохімія, рідкісні метали, озерні води, мінералізація, гранітні інтрузії*

Recommended for publication by Ye. M. Sapargaliyev, Doctor of Geological and Mineralogical Sciences. The manuscript was submitted on 25.03.21.