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METHODOLOGICAL RECOMMENDATIONS FOR THE APPLICATIONS OF THE MINERAL RESOURCES CATEGORY IN MONGOLIA TO THE RELATED MINERALS

(LITHIUM, CAESIUM)

ULAANBAATAR

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The METHODICAL RECOMMENDATION applied for classification of mineral resources and certain type deposits' reserves of Mongolia

LITHIUM, CAESIUM DEPOSITS

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It is intended for employees of business entities and enterprises operating within the subsoil use, regardless of the affiliation and form of ownership. These methodological recommendations are useful for obtaining geological and exploration information, its quality and completeness in making decisions on further geological exploration work, putting the explored deposits into production, as well as renovating existing mining and processing plants and constructing new ones.

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APPEDIXES

One. Basic Terms

1.1. This recommendation has been developed based on the provisions of following laws, orders, procedures and guidelines such as “State Policy on Mineral Resources”, Article 16 of the “Mineral Resources Law”, “Action Plan of the Government of Mongolia for 2016-2020”, “Regulations on mineral prospecting and exploration activities” approved by Order A/270 of Minister of Mining and Heavy Industry of Mongolia on 5th September of 2018, and “Classification and instructions on mineral resources and deposit reserves” approved by Order No. 203 of the Minister of Mining and Heavy Industry of Mongolia on September 11th of 2015. The methodological recommendation includes recommendations for the application of the classification of solid mineral resources and deposits to lithium and caesium deposits.

1.2. The methodological recommendations are intended to provide practical assistance to companies, geologists, explorers and miners holding exploration and mining licenses to prepare lithium and caesium deposit estimates, register reserves in the state unified registration of mineral resources, and move reserves.

1.3. Lithium is an element in Group 1 of the Mendeleev Periodic Table, the third element in the group of alkali metals with an atomic mass of 6.94. Lithium is light gray, silvery gray, with a metallic sheen.

In nature, there are two isotopes, ^{6}Li and ^{7}Li, with the ^{6}Li isotope accounting for 7.59% and the ^{7}Li isotope accounting for 92.41%. Lithium nucleus consists of 3 protons and 4 neutrons and has 1S1 electron, +1 valence in the outer layer, very high chemical activity, excellent electrical and thermal conductivity. It is the lightest metal and melts at the lowest or 180.5°C and boils at 1330°C, 0.53 g / cm^3 density. Lithium has a high heat capacity (close to water heat capacity). The radius of the three-electron lithium ion is $78*10^{-12}$□, the minimum atomic radius of lithium is $157*10^{-12}$□, and it has a high hardness due to its transparent lattice compared to other alkali metals. Lithium has the unique ability to react with beryllium, magnesium, aluminum, copper, and lead to form alloys. The chemical composition of these metals, which are highly chemically active, is the electrolysis of chlorides - the salts of Al, Mg, and Ca, which provide chemical strength.

Pure metal lithium burns in air at 640°C. Lithium reacts with hydrogen at 500-800°C to form hydrides and reacts strongly with water ($LiH+H_2O = LiOH+H_2+130kJ$). It combines with gaseous ammonia to form lithium amide $LiNH_2$, and with carbon to form lithium carbide (Li_2C_2).

Lithium is not used directly as a metal. This is because lithium nitrite combines with atmospheric nitrogen to form Li_3N. Lithium oxide readily combines with water to form hydrated lithium ($LiO_2 + H_2O = 2LiOH$).

1.4. Lithium was first discovered in 1817 by the Swedish chemist Johan August Arfwedson. The name is derived from the Greek word λίθος-lithos-stone.

Lithium is found in the earth's crust at an average of 20-70 g/t, and at 0.12-0.25 g/t in sea and sea water. Rarely, some plants contain up to 69-0.6 g/t. In the 19th century, lithium was used in small amounts as a drug. Since the 1950s, it has been established that the ^{6}Li isotope can be used as a source of tritium for nuclear reactions, making lithium the main raw material for future controlled (manageable) nuclear thermal energy. In recent years, lithium has been used mainly in aluminum production, and the addition of 3-5% lithium carbonate to aluminum electrolysis has been shown to save electricity by about 20 percent and reduce fluoride emissions by at least 25 percent.

Lithium-spodumen (iron-depleted), petalite, and lithium carbonate compounds are found in products such as ceramics, glass, and sital. Sital-glass porcelain is a product used in technical, construction and decorative industries, and it is available in lithium, brown-barium, magnesium, titanium and other types.

Lithium hydrochloric acid does not lose its quality even in the temperature range from -60°C to +60°C, and this quality is used as a lubricant.

The most promising applications of lithium are in the aerospace and aerospace industries, which use metallic lithium-aluminum alloys (96% Al, 3% Li and others). The addition of lithium to the aluminum alloy reduces the weight of the aircraft by 10% and prolongs the life of the aircraft by 20%.

It is widely used in charge accumulators, charge storage electrolytes and electrodes based on the chemically active properties of lithium, its ability to easily lose and retain 1 electron in the outer layer, its high electrical potential, and its electrochemical properties. Lithium-ion batteries are widely used in large-scale industrial vehicles, from simple rechargeable batteries to fast-charging, high-capacity batteries. It is widely used in the manufacture of small, rechargeable batteries for the heart, as well as in the production of heart-supporting batteries (stimulators), cameras and video cameras, computer memory devices, and electric car batteries.

Lithium hygroscopic compounds are widely used in aeration equipment (spacecraft cabin), coatings (lubricants), heat-resistant enamels for jet and turbojet engines, high-strength cements, varnishes, paints and pharmaceuticals.

Global lithium consumption is expected to increase to 197,000 tons of Li_2CO_3 equivalent in 2016 and 1,008,000 tons of Li_2CO_3 equivalent in 2026 (Table 1).

Lithium consumption in the world market in 2016 and 2026

(Clara et al, 2016)

Table-1

Lithium consumption industry	Percentage of consumption, %	
	2016	2026
Batteries and accumulators	42	86
Manufacture of ceramics and glass	24	6
Oil and lubrication	7	2
Manufacture of polymer rubber	5	1
Metallurgical flux powder	4	0.8
Ventilation and air purification	2	0.4
Pharmaceutical production	1	0.2
Other uses	15	5.6

1.5. Caesium is a yellowish, shiny white metal. It has a density of 1.87 g/cm^3, is the softest of the metals, and melts at the lowest temperature (+28°C). Caesium has the unique property of being the most easily ionized by sunlight and cosmic rays.

Caesium is used as a source of electricity by heating, and based on this property, it is widely used in the manufacture of photocells, electron-optics (photoelectrons), and solar panels.

The high atomic mass (132.91) and low boiling point open up the possibility that caesium can be used to fuel space rocket engines and increase the efficiency of plasma generators. In addition, it has the potential to be used for the conversion of thermal energy into electricity (magnetohydrodynamic generators, thermal electronic converters etc.).

1.6. About 30 of the more than 150 minerals of lithium are known, mostly silicates and phosphates, but lithium is extracted from carbonates and other minerals in addition to silicates and phosphates (Table 2). Today, minerals such as lithium spodumene, lepidolite, petalite, amblygonite, and cynnvaldite are used for industrial purposes. 65% of lithium reserves are in lake deposits, 25% in endogenous deposits and 10% in other deposits.

The main minerals for the production of lithium-caesium

Table-2

Minerals	Chemical formula	Li_2O, Cs_2O content, %	Mix-element	Density, g/cm^3
Lithium minerals				
Spodumen	$LiAl(Si_2O_6)$	Li_2O 5.9-7.6	Rb, Sc, Ga, Sn	3.1-3.2
Amblygonite	$LiAl(PO_4)F$	Li_2O 7.6	Sn, Ga, Be, Ta	3.0-3.1
Montebrasite	$LiAl(PO_4)OH$	Li_2O 7.0-9.0	-	3.0-3.1
Petalite	$LiAlSi_4O_{10}$	Li_2O_3 3.4-4.1	Ba, Sr	2.4
Eucryptite	$LiAlSiO_4$	Li_2O 6.1	Ba, Sr, Ga, Be, Sn	2.6-2.7
Lepidolite	$KLi_{1.5}Al_{2.5}Si_3O_{10}(F,OH)_2$-$K_2Li_3Al_5Si_6O_{20}(F,OH)_4$	Li_2O 4.1-5.5	Ge, Tl, Ga, Rb, Cs	2.8-2.9
Zinnwaldite	$KLiFe\ Al_2Si_3O_{10}F_2$	Li_2O 2.9-4.5	Rb, SCs, Be	2.9-3.2
Polylithionite	$KLi_2AlSi_4O_{10}(F,OH)_2$	Li_2O 5.5-8.8	Rb	2.8
Zabuyelite	Li_2CO_3	Li_2O 40.44		2.09
Jadarite	$LiNaB_3SiO_7(OH)$	Li_2O 7.28		2.45
Hectorite	$Na_{0,3}(Mg,Li)_3Si_4O_{10}(OH)_2$	Li_2O 1.17		2.5
Caesium minerals				
Pollucite	$CsAlSi_2O_6*H_2O$	Cs_2O 20-36.1	Rb, Be, Li	2.8-2.9
Caesium biotite	$(K,Cs,Rb)\ (Fe,Mg)_3\ [Si_3AlO_{10}](F, OH)_2$	Cs_2O 6 хүртэл	Li, Ga, Rb	3.0-3.1
Avogardite	$(K,Cs)BF_4$	Cs_2O 23.6		2.6
Pezzottaite	$Cs(Be_2Li)Al_2Si_6O_{18}$	Cs_2O 15.8		3.0
Londonite	$CsAl_4Be_4(B,Be)_{12}O_{28}$	Cs_2O 8.4		3.3
Pautovite	$CsFe_2S_3$	Cs 35.9		3.4
Sokolovaite	$CsLi_2AlSi_4O_{10}F_2$	Cs_2O 29.11		

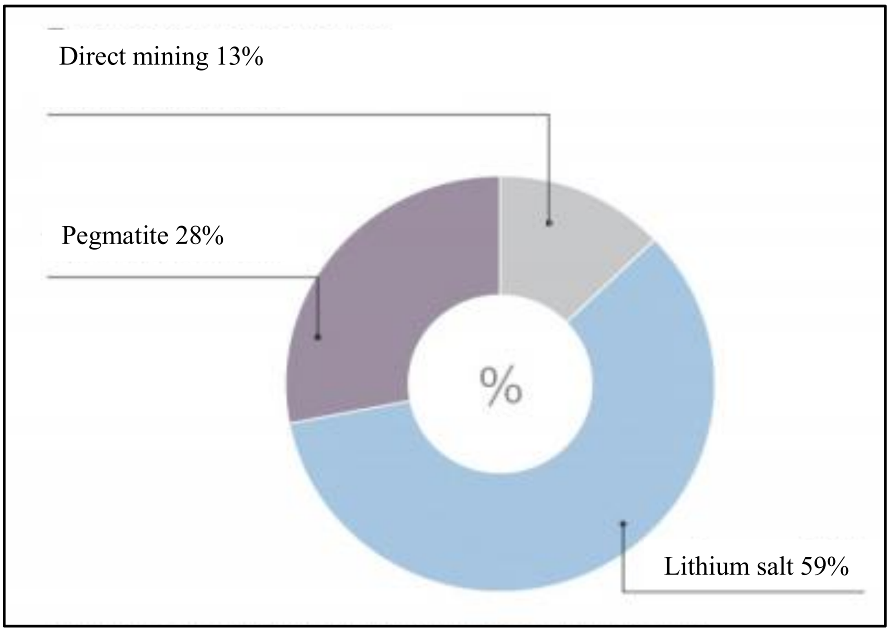
1.7. Caesium is isomorphic in nature, forming single minerals such as pollucite, which is composed of minerals with similar structures such as mica, beryllium, and astrophyllite, and caesium biotite, which contains 4-6% Cs_2O. Lithium and caesium minerals are highly unstable in the ore body and in the main and auxiliary components of the deposit.

1.8. The main sources of lithium mining in Russia are spodumene, sometimes petalite, lepidolite, rarely amblygonite, and rare metal pegmatite and granite containing eucalyptus. In other countries, lithium is extracted from lithium-enriched water, dried lake saline solution (rapa), saline water from groundwater and highly evaporated reservoirs, and mineral groundwater from petroleum iodobromine (Figure 1, Table 3).

Lithium mineral and chemical products are used fully in foreign countries. Rare metal pegmatite produces spodumen mineral concentrate (lithium pyroxene LiAl (Si_2O_6)), small amounts of petalite (lithium spar $LiAlSi_4O_{10}$), lipidolite $KLi_{1.5}Al_2.5Si_3O_{10}(F,OH)_2$, and little amount of amblygonite (LiAl (Si_2O_6).

Types of lithium chemical compounds (SignumBox, 2011)

Figure-1



During the mining of metasomatic metamorphic granite and various types of greisen deposits, it is possible to extract lithium from mica such as cinnavaldite, lepidolite and polylytinoite in the form of by-products.

1.9. Lithium and caesium deposits in rare metal pegmatite are divided into two main types of production: lithium and lithium-caesium-tantalum (Table 3).

Lithium deposits in pegmatite include the Zavitinskoye, Kolmozerskoye, Tagtygskoye deposits in Russia and the Kings Mountains in the United States. The ore bodies are elongated linear, parallel, steeply sloping pegmatite veins, hundreds of meters to kilometers long along the regional fault zone. The thickness of the veins varies from 0.5-1m to 2-25m. The amplitude of spodumenary mineralization along the vertical axis reaches 3-3.5 km. The host rock is metamorphosed to cordierite-amphibole facies. Pegmatite ore bodies are usually weakly zoned, with marginal zones consisting of small or medium-grained quartz-albite or quartz-microcline aggregates. In the central zone, the size of the spodumen body is very wide, reaching 0.5-1.5 m, and the spodumen crystals are often located horizontally on the boundary surface of the ore body. This should be taken into account when testing boreholes. The content of spodumene in the ore is 15-25% and Li_2O is 0.5-1.5%. Ancillary minerals are Ta_2O_5 0.005-0.01%, Be 0.04-0.07%, Sn 0.03-0.08% and feldspar.

Lithium-caesium-tantalum deposits in pegmatite are represented by belt-shaped, sloping, plate-like, or mesh-like ore bodies, and the mineral content is uneven and unstable (especially pollucite in the veins). Occasionally, this type of ore contains lepidolite deposits (0.3-1.3%

Cs_2O) with almost lithium and caesium minerals in the form of meshes along the axis of pegmatite bodies.

The main mineral of lithium ore is spodumene, which belongs to the Al-Si group. Spodumene contains 8% Li_2O, 64.5% SiO_2 and 27.5% Al_2O_3. The melting point is 1380°C. Spodumene is found in nature in the form of crystals of various sizes with quartz, feldspar, ambligonite, beryllium, columbite and tantalite. The spodumen is glassy, gray, greenish-gray, and yellow-green in color. Spodumene crystals, 16 meters long and weighing 65 tons, were found in the Dakota deposit in the United States.

Lepidolite, cinnvaldite, and petalite have a lower lithium content than spodumene, containing 1.5-5.5% Li_2O, 46.9-60.1% SiO_2, 11-28.8% Al_2O_3, and 9% fluoride. The main impurities are rubidium (Rb_2O 3.7%) and caesium (Cs_2O 1.5%). The crystals are platelets, the aggregates are leaflets and fine scales. It is urple, red, pink, gray and blue-pink.

Amblygonite contains phosphate, lithium and aluminum. Lithium content reaches 10.1% Li_2O, P_2O_5 54%, Al_2O_3 34% and 9% fluorine. Amblygonite accounts for a small percentage of ore reserves and is white, yellow, gray, and bluish-green in color.

In addition to spodumene and lepidolite, lithium is found in petalite, eucryptite, montebrazite, and lithium muscovite. In such deposits, tantalum is considered to be the main mineral and its Ta_2O_5 content varies from 0.01 to 0.04%. The main minerals in tantalum are columbite-tantalum, voginite and microlite. The by-products are tin Sn 0.04-0.1% and beryllium Be 0.02-0.07%.

Caesium-biotite metasomatite in the vicinity of pegmatite is a relatively rare type of caesium ore. Caesium-biotite metasomatite is located between the pegmatite veins and makes up 10% of the ore volume of the deposit and forms a bandwidth of 10-1 m in the exocontent zone. The main mineral of the ore is caesium biotite.

Caesium ore bodies are represented by linear, elongated meshes and a series of small bodies, which are identified only by sampling.

Spodument granite lithium-tantalum deposits include the Alakhinskoye deposit in the Altai Mountains. The ore body of the deposit is a convex bed (0.4 km^2) at the edge of the spodument granite massif, surrounded by a cut-off content of Ta_2O_5 0.007%. The main minerals of lithium are spodumene and petalite and montebrazite. Tantalum minerals are tantalite and microlite. Pollucitis was found in small amounts. The average lithium content of the ore is 0.71% Li_2O.

The main type of lithium deposit production is brine, which accounts for 59% of the world's lithium production (Figure 1). These types of lithium-bearing deposits are formed in closed basins of lakes with high evaporation rates. The largest deposits are in the Andes and China, and the smallest deposits are in America and North Africa. Lithium-containing solutions of salt deposits associated with the Lacustrine Evaporation Lake are enriched with minerals found in the rocks of the region and have many different compositions compared to marine evaporation. Here, the saline solution is formed as a result of the interaction of rocks and groundwater due to weathering and geothermal processes of volcanic and igneous rocks in the region. There are four main natural raw materials for this type of lithium mining: surface water, near-surface fetal water, salt lake (CO_3)-Cl-(K)-Mg-Na and (SO_4)-Cl-(Mg)-Na. Other chloride saline groundwater is a promising type of production.

Main types of production and ore of lithium-caesium deposits

Table-3

Type of production	Structural-morphological types and host rocks	Types of natural (mineral) ores	Main ore grade content in ore,%	Minor components	Type of ore production (technology)	Deposits
Lithium in pegmatite	Gabbro- anorthosite, amphibolite, schist, vein in limestone	Spodumene	Li_2O 0.5-1.5	Ta, Be, Nb, Sn, feldspar	Tantalum-niobium-beryllium-lithium (gravity-flotation-hydrometallurgy)	Zavitinskoe, Kolmozerskoe, Tastygskoye, Russia; Kings Mountain, USA
Lithium-caesium-tantalum in pegmatite	Amphibolite, crystal schist, vein and lens in the gneiss	Spodumene-beryllium-tantalum; pollucite-spodumene-tantalum; spodumene-vodjinite-tantalum	Ta_2O_5 0.01-0.04; Cs_2O 0.1-0.8; Li_2O 0.3-1.5; BeO 0.02-0.07	Nb, Sn, Ga, feldspar	Beryllium-lithium-caesium-tantalum (gravity-flotation-hydrometallurgy)	Vishnyakovskoye, Voronezh-Tundrovskoye, Russia, Bakennoye, Kazakhstan, Bernick Lake, Canada
Lithium-tantalum in spodumene granite	Granite with spodumene	Tantalite-spodumene	Li_2O 0.5-1; Ta_2O_5 0.008-0.014;	Nb, Rb, Cs	Lithium-tantalum (gravity-flotation-hydrometallurgy)	Russia Alahinskoe
Hectorite-lithium containing clay mineral	In the volcanic caldera, shallow sediments and mesh-like bodies in volcanic rocks	hectorite clay magnesium-lithium smectite	Li 0.53%	Li, K		Kings Valley, Northern Nevada (USA), Argentina, Turkey, Mexico
Jadarite	Thick belt, layer type	Brown and lithium-bearing clay like sediments	B_2O_3 47.2, Li_2O 7.3%	B, Li		Serbia, Jadar Valley

Two. Grouping of deposits for complexity of geological setting for exploration purposes

2.1. Lithium and caesium deposits are classified in one of the groups II, III and IV by the Order No. 203 of the Minister of Mining and Heavy Industry of Mongolia dated on September 11, 2015 depending on the size and shape of the ore body, their thickness, internal structure, changes in structure and features.

Most of the proven lithium ore deposits belong to group II, and caesium ore deposits belong to groups III and IV.

Group II has complex geological formations, ore bodies with steeply sloping, elongated linear shape (1-2 km in length), numerous veins with unstable thickness, uneven distribution of lithium oxide deposits (Polmostundrovskoye, Tastygskoe deposits in Russia) and granite deposits. large muscovite-spodumene deposits (n*100 x n*100 m) in the periphery of the massif.

In Group III, the geological formations of deposits and ore bodies are very complex, the ore bodies are 50-100 to 500 m long, with a large number of unstable veins or vein-like metasomatic deposits, and the mineral content is extremely unevenly distributed (Goltsovoye deposit in Russia).

In Group IV, the geological formations of the deposit and ore body are represented by highly complex, pollucite-containing pegmatite bodies. The ore bodies are small veins, meshes, nest-shaped, fractured and have a high caesium oxide content, but the ore bodies are branched with non-ore bearing rocks (Vasin Mylk deposit in Russia).

2.2. Which group a deposit (ore segments) belongs to is determined by the degree of complexity of the geological formation of the main ore bodies that contain 70% or less of the ore that may be economically viable for the deposit.

2.3. Statistical indicators of changes in the basic quality of mineralization can be used to classify a deposit (Appendix 1).

Three. Geological setting of deposit and studies of ore mineral component

3.1. The size of the deposit to be explored requires a topographic map with a scale appropriate to the geological formation and topography of the deposit.

Topographic and background maps of lithium and caesium ore deposits will be prepared on a scale of 1: 1000 - 1:10 000. All exploration and production excavations (ditches, trenches, mines, underground excavations, boreholes), geophysical survey lines, ore body exits, and mineralization zones will be determined by instrumental measurements and mapped. Underground excavations and boreholes will be connected to the surveyor's map and mapped. Mining horizons (levels) shall be designed on a scale of 1: 200-1: 500, and a unified background map shall be designed on a scale of 1: 1,000 or less.

The coordinates of the points where the ceiling and bottom of the ore body intersect will be determined by the boreholes, and their location will be plotted on the background images and section planes.

Topographic mapping shall be performed by a licensed and authorized professional organization. The performance report shall be prepared in accordance with the relevant procedures and shall include the name of the deposit, date of completion, instrument name, mark, measurement accuracy, methodology, fixed point connection and other information. The coordinates of the image will be issued by the WGS-84 system based on the Order No. 127 of the Director of the Mineral Resources Authority in 2010. Depending on the image type, scope, and purpose, the coordinates are displayed in linear (UTM) and traditional geographic units (degrees, minutes, seconds).

3.2. The geological formation of the deposit will be studied in detail and geological sections, plans and projections will be made on a scale of 1: 1 000 - 1:10 000 (depending on the size and complexity of the deposit) and, if necessary, shown in block diagrams and models (three-dimensional). The geological, geochemical and geophysical survey materials of the deposit provide information on the shape and size of ore bodies, their conditions, internal structure, continuity (subsidence or subsidence characteristics of ore bodies), characteristics of changes in bearing rocks, folded structure and continuous cracks and their relationship, and provide sufficient understanding and create conditions for classifying the deposit's reserves.

Prospective areas will also be identified based on the geological boundaries of the deposit and exploration criteria, and the resources discovered in the area will be assessed by P_1.

Ore bodies and surface objects are studied in mountain minerals and shallow boreholes. Changes, characteristics of ore technology, main and ancillary resources, etc. will be studied, types of ore production (technology) will be identified and reserves will be calculated for each of them.

Depth exploration of the deposit will be carried out in conjunction with borehole drilling (mining in highly complex deposits) and geophysical survey methods will be used in surface and borehole and mountain excavations.

Exploration methods include mining and drilling, their ratios, types of excavations, drilling methods, exploration grid shapes, densities, sampling methods, and methods to estimate reserves according to the degree to which they are grouped into a complex group of geological formations. The deposit group is determined based on the results of the exploration work, the specifics of the geological formation of the deposit, the experience of exploration and exploitation of similar deposits.

Optimal selection of exploration methods and equipment was made taking into account the distribution characteristics of the deposit, distribution, spatial location, ore structure-texture features, ore mineral accumulation, core yield, selective erosion, enrichment and pollution during sampling. In addition, the time, technical and economic parameters of the exploration work will be calculated in different ways and used for selection.

3.3. Core sampling is required to determine the location of ore bodies and host rocks, their thickness, structure of the ore body, changes around the mineralization, mineral composition of the ore, distribution of production types, texture and structure, so the core should be highly representative and yield not less than 90%. The results determined linearly by the core yield should be monitored regularly by weight and volume.

Sampling of high-yield core, which is representative of the useful plant grade and the thickness of the ore intervals, shall be carried out, and cores and sludges shall be sampled together in areas of selective wear.

In areas where selective erosion is more likely (more likely for lithium and caesium), the use of high-yield drilling technology and the introduction of control excavations will determine the level and cause of selective erosion. If the presence of selective wear is thus determined, a correction factor shall be calculated and used as a result of the core sampling.

In order to improve the reliability and information capacity of the drilling operation, it is necessary to select and use borehole geophysical surveys based on modern geophysical survey methods that are suitable for the geological and geophysical conditions of the deposit. A comprehensive logging survey will be conducted in all boreholes drilled throughout the deposit to ensure the correct location and size of the ore interval.

The azimuth and deflection angles of the boreholes are determined for every 100 m or more of vertical drilling, 20 m or more in underground and all sloping boreholes. The results of these measurements can be used to calculate geological sections, horizontal plans and ore section thicknesses.

If the boreholes intersect with the underground excavation, the location of the intersection point will be determined by surveyor measurements. The slope of the borehole shall be drilled so that the ore body is cut at an angle of at least 30°. When cutting steeply sloping ore bodies at sharp angles, deliberate tilting of the borehole may be used. In order to improve exploration results and save costs, it is beneficial to drill multi-bench boreholes and underground drill-type drilling from underground excavations.

The coordinates of all boreholes drilled in the deposit were determined by topographic measurements. All necessary information, such as borehole type, equipment used, coordinates, date, depth, azimuth, deflection, diameter, number of samples taken, company performed, etc., will be prepared and stored electronically and in hard copy. Drilling reports need to be compiled on a daily basis and integrated into a database.

3.4. Excavations are a tool for monitoring drilling and geochemical and geophysical surveys, as well as for technological sampling. In the case of a sufficient amount of exploration in the representative part of the deposit, changes in the fall and elongation of the ore body and its continuous state will be determined in detail. Low-thickness bodies were studied by continuous tracking and vertical excavations, while thick-bodied bodies and stockwork bodies were studied by quartz, medium and horizontal excavations. Excavations will be concentrated in the detailed study areas of the deposit, primarily at the extraction levels.

3.5. The location of exploration excavations and boreholes and the distance between them are determined for each structural-morphological type of ore body, and their size, location and density are determined by geological formation characteristics, geochemical and geophysical survey data (surface, borehole, mine). Table 4 summarizes the density of exploration grids used in the exploration of lithium and caesium deposits in the countries of the former Soviet Union and the Commonwealth of Independent States, which can be optimized for geological exploration planning. Based on a detailed study of each deposit, geological, geochemical, geophysical surveys of similar deposits, and analysis of exploitation data, the density and optimal shape of the exploration grid will be determined. Statistical and geostatistical processing will be carried out based on the distribution of lithium and caesium content, and based on the results, the density and efficiency of the exploration grid will be confirmed.

3.6. More detailed exploration has been carried out in some parts of the deposit to confirm the reliability of the resource estimates. The number and size of precision sections shall be determined by a qualified person and resource benchmark parameters shall be selected based on the preliminary feasibility study. These areas will be explored and sampled more closely than other parts of the deposit.

Exploration grid density information used in the exploration of lithium and caesium ore deposits

Table-4

Deposit groups	Description of the ore body	Type of excavation	The distance between excavations that intersect the ore body corresponding to the resource grade (m)			
			B		C	
			Суналын дагуу	Уналын дагуу	Суналын дагуу	Уналын дагуу
II	Numerous vascular bodies with unstable thickness, uneven distribution of lithium oxide, elongated linear shape, steep fall	Drift (Schtrek)	Continuously followed	40-60	-	-
		Ort	40-60	-	-	-
		Hidden vertical excavation (восстающий)	80-120	Continuously followed	-	-
		Boreholes	100	50	100-200	50-100
III	Vein thickness is unstable, mineral content is extremely unevenly distributed, grouped veins or vein-like shape, metasomatic deposits	Drift (Schtrek)	-	-	Continuously followed	20-30
		Ort	-	-	20-30	-
		Hidden vertical excavation (восстающий)	-	-	60-80	Continuously followed
		Boreholes	-	-	40-50	40-50
IV*	Pollucite-containing pegmatites and ore bodies are small veins, meshes, nest-like, ruptured, with a high caesium oxide content but branched with non-ore rocks.	Drift (Schtrek)	-	-	Continuously followed	10-15
		Ort	-	-	20	-
		Hidden vertical excavation (восстающий)	-	-	Each ore body has at least one cross section	
		Boreholes	-	-	20-25	20-25

* It is based on data from the density of exploration mesh in small ore bodies with very complex formations, unstable (intermittent) caesium oxide content.

Most of the reserves of the Group II deposit are estimated at real (B) grade, and most of the reserves of the III group deposit are estimated at possible (C) grade. In the detailed study of a Group III deposit, it is recommended that the exploration mesh be at least 2 densities thicker than the possible (C) grade mesh density.

When using geostatic methods in the calculation of deposit reserves, the density of the exploration grid shall be ensured at the level of reliable evaluation of the optimal formula of interpolation (kriging, inverse distance method, etc.).

Detailed study of the deposit will be carried out in the part that reflects the shape, location and main characteristics of the ore body that makes up the main part of the deposit's reserves. As far as possible, these bodies should be located within the reserves to be mined in the first instance. The number and size of the deposit to be studied in detail shall be determined by the person engaged in exploration and mining from time to time.

For intermittent mineralized deposits where it is not possible to identify each of the mineralized parts, the mineralization coefficient can be used to estimate the reserves within the general scope of mineralization and to identify the parts that meet the standard requirements.

The detailed geological information of the explored area will be used to determine the deposit group, to select the appropriate exploration methodology, equipment, exploration and sampling grid density, to improve the optimization of resource estimates, and to compare exploration and mining in other parts of the deposit. Exploration and production information for the deposits being mined will also be used for detailed research.

3.7. All excavations, ore bodies and areas found on the surface are documented. The results of the sampling shall be mapped to the original document and checked against the geological description.

Whether the composition and quality of the initial documentation is in accordance with the geological features of the deposit, whether the spatial location of the structural elements is correctly determined, and the design of the drawings and their inscriptions are regularly verified by a qualified person. The quality of geological sampling and geophysical measurements should be evaluated (sample weight and sampling cross-section stability, sampling location appropriate to the geological formation of the deposit, sampling steps and continuity, control sampling, results, etc. .).

3.8. All ore sections, exploration excavations and ore shafts are fully sampled to assess mineral quality, demarcate ore bodies and estimate reserves.

At the initial stage of the appraisal and exploration work, exploration equipment, sampling methods (geological and geophysical) will be selected based on the geological characteristics of the deposit and the physical properties of the minerals and host rocks.

Sampling of lithium and caesium ore deposits can be performed using nuclear geophysical methods. The sampling method chosen should be efficient, economical and reliable. When different methods are tested, their results are compared for accuracy and reliability. In the case of sampling by methods such as cores, grooves, dots, etc., their comparative quality assessment shall be carried out in accordance with established methods and techniques.

3.9. In order to save labor and costs of geological sampling, the sampling areas should be selected based on the results of measurements made by logging, nuclear geophysics and magnetic methods. The following principles shall be followed in exploration sampling. These include:

- The sampling grid is stable and the mesh density is determined by the geological characteristics of the study area and is usually based on the experience of a similar deposit or a new object is based on an experiment; Mandatory sampling in the direction of maximum mineralization, cross-sectional cutting of ore bodies (especially boreholes) in exploration excavations, and control or comparison of the results of sampling in cases where the representativeness of the specimen is questionable have been demonstrated.

- The ore body shall be fully covered and tested continuously in sections of a certain length. The length of the specimen shall penetrate the host rock to a length not less than the thickness of the non-standard ore within the ore body. Ore bodies with uncertain geological boundaries shall be sampled from all exploration sections and from the sections required for a deposit with a definite boundary with a sparse grid. Sampling will include ore bodies found in surface excavations such as ditches, trenches and trenches, as well as weathered and oxidized parts of the ore.

- The natural type of ore and each piece of mineralized rock will be tested separately. The length of a unit sample or section length shall be determined taking into account the internal structure of the ore body, changes in the composition of the substance, texture-structural features, physical-mechanical and other properties of the ore. The length of the specimen should not exceed the reference values, such as the minimum thickness of the ore body and the maximum thickness of the voids within the reserve.

The core output is sampled at different intervals. If the core is worn out during drilling, the core and drilled debris (sludge, dust, etc.) will also be sampled. Small fragments from the interval should be sampled and analyzed separately, as in the case of core testing. If the mineral distribution of the ore is very variable, the core should not be split and the whole should be tested directly.

The entire thickness of the ore body is cut and samples are taken from both sides of the excavated rock excavations and underground vertical excavations. Excavation sampling along the elongation of the ore body is usually performed on the bench and rarely on the wall after each progress. Horizontal excavation sampling of vertically inclined ore bodies shall be performed at a stable height above the excavation footing.

The main parameters, such as the cross-section of the specimen, the length of the section, and the weight, are determined by comparative methods and experimental studies. In addition, the study should examine samples for lithium-containing minerals such as spodumene, lepidolite, and pollucite to determine whether they are enrichment and decreasement of samples.

Experiments and research have been carried out on whether radiometric ores can be used for sampling and preliminary classification of ores by technological type and for quality assessment.

Sampling quality control is performed for each type of work, such as sampling, processing, and analysis, and for each type of natural ore.

The location of the specimens shall be verified in a timely manner in accordance with the geological setting, and the specimens shall be monitored to ensure that the ore body is completely cut to thickness, the specimen weight is stable, and the groove specimen cross section, core diameter and actual weight are consistent with theoretical values. Depending on the density of the ore, the sample weight may vary by ±10-20%.

The groove sampling control is performed by repeated (control) sampling parallel to the main sample, and the core sampling control is performed by the remaining part of the duplicate.

Geophysical measurements shall be monitored by the results of repeated measurements under the same conditions, as well as by comparison with the results of groove and core sampling from non-selective wear sections.

Sampling and geophysical measurements shall be repeated if the results of the sampling and geophysical measurements exceed the permissible limits.

The sampling methodology can be monitored by bulk sampling as a guide to the relevant guidelines. Deposit mining data can be used to monitor the results of bulk samples and sampling methods can be used to determine process volumes and rock mass volumetric weights.

The number of control samples should be sufficient to statistically process the test results and to identify random and persistent errors. In the event of persistent sampling errors during the inspection, the correction factor shall be calculated and decided.

3.10. Sample processing shall be performed according to the scheme developed for each deposit or by the scheme used for similar deposits. The processing of the main and control samples shall be carried out according to the same scheme. Monitoring of all sample processing activities should be conducted as well. This includes regular monitoring of the rationale for the "K" coefficient and adherence to the sample processing scheme. If the specimen has a very different ore mineral content during processing, the contamination/contamination of the surface of the crushing equipment should be monitored regularly. Large control samples should be processed according to a specific program.

3.11. The chemical composition of the ore is examined to determine the presence of primary and secondary minerals, toxic impurities, and slag-forming compounds. Their content in the sample shall be determined by chemical, physicochemical, mineralogical, physical, geophysical and other analytical methods.

The ancillary minerals in the ore will be implemented in accordance with the "Methodological Recommendations for Comprehensive Study of Mineral Deposits and Estimates of Ancillary Mineral Resources" which is being implemented in Mongolia. Additionally, "Методические рекомендации по комплексному изучению месторождений и подсчету запасов попутных полезных ископаемых и компонентов" by Russia can be used.

In all samples, the content of the main minerals is determined and the results are used to separate the ore body and to estimate the reserves.

The analysis of group samples will determine the accompanying minor components and toxic impurities.

When simple samples are grouped into groups, the main type of ore shall be grouped in a way that the size of its main and ancillary components is determined and the pattern of content change in all directions of the ore body space is evaluated evenly.

3.12. Occasional errors are determined by internal control. To do this, a different number to the duplicate of the main sample sent for analysis is given and tested in the laboratory where the main test was performed, within the next quarter.

In order to detect and evaluate systematic errors, they should be performed by another accredited laboratory with external control. For external inspection, a duplicate of the internally inspected sample shall be sent to the laboratory where the main test was performed.

Where standard specimens are available, standard specimens, together with standard specimens to be sent for analysis, shall be ordered and tested for external control.

Internal and external control covers all types of ore deposits and all content groups. All specimens with extremely high concentrations of useful components must be retested.

3.13. Internal and external monitoring should be performed periodically (quarterly, semi-annually, etc.) and on a regular basis for each content group. Monitoring should be performed on 5% of the total sample if the number of specimens is large (2000 and more per year), and on a minimum of 30 samples from each content group during the control period.

3.14. For each content group, internal and external monitoring information will be developed for each period of analysis (quarterly, semi-annually) and for each, laboratory analysis methodology is performed. If a systematic error is found in the results of a standard sample test, it shall be evaluated in accordance with the methodology for statistical processing of the test data.

The difference between the relative mean squares determined by the internal control shall not exceed the specified value (Table 5.). If the discrepancy exceeds the values given in the table, the test results for that group shall be invalidated and retested under internal control. During the re-testing, it is necessary to find the cause of the error in the laboratory that performed the basic test and take steps to correct it.

3.15. In the event of a systematic error in the external inspection of the sample, an arbitral tribunal shall be convened. A copy of the ordinary sample with the main and external audits shall be sent to the arbitral tribunal. 30-40 samples from each content group with systematic errors will be monitored. If a "standard" specimen is available, the standard specimen shall be encrypted and sent to the external arbitration order. The results of 10-15 control tests should be obtained for each standard sample.

If the arbitral tribunal proves that there is a systematic error, it will detect the error in the work of the laboratory that performed the basic analysis and take action to correct the error. It also decides whether all samples in the class need to be retested, or whether the test results can be corrected using coefficients. An error correction factor shall not be used without an arbitral review.

3.16. Mineral composition of ores, their structural-textural features and physical properties are studied by mineralogical-petrographic, physical, chemical and other analytical methods. In addition to identifying minerals by analysis, a qualitative assessment of their distribution will be made.

Particular attention should be paid to lithium-bearing minerals (especially spodumene, petalite) and caesium-bearing minerals (pollucite) to determine their number and chemical composition. These minerals (lithium and caesium-bearing minerals) have been shown to ally with each other and with other minerals, as well as particle size and distribution. Because the composition of lithium and caesium minerals is uneven and highly variable, their content fluctuations (by Li_2O, Cs_2O contents) should be studied for each ore body and at the deposit level.

The permissible amount (%) of analytical case errors by content groups (relative average square)

Table-5

Components	Content group in the ore*, %	The permissible size of the relative square difference, %	Components	Content group in the ore*, %	The permissible size of the relative square difference, %
LiO_2	>1	7	Ta_2O_5	0.01-0.02	25
	0.5-1	10		0.005-0.01	30
	0.2-0.5	13		<0.005	30
	0.1-0.2	17	Nb_2O_5	0.1-0.2	16
	0.05-0.1	22		0.05-0.1	20
Cs_2O	>1	12		0.02-0.05	23
	0.5-1	15		<0.02	30
	0.2-0.5	17	Sn	0.1-0.2	15
	0.1-0.2	22		0.05-0.1	20
	0.05-0.1	25		0.025-0.05	25
Rb_2O	>1	12		<0.025	30
	0.5-1	15	K_2O	>5	6.5
	0.2-0.5	17		1-5	11
	0.1-0.2	22		0.5-1	15
	0.05-0.1	25		<0.5	30
BeO	0.2-0.5	10	Na_2O	>25	4.5
	0.1-0.2	12		5-25	6
	0.05-0.1	15		0.5-5	15
	0.02-0.05	20		<0.5	30
	0.01-0.02	22			

* If the content group in the ore of the deposit is different from that specified here, the relative average square shall be determined by interpolation.

Mineralogical studies will study the distribution, and distribution of primary and secondary components and toxic impurities and determine their percentage in mineral compounds. This study theoretically considers the possibility of extracting them and extracting them by resource (spodumene, petalite, lepidolite, pollucite minerals) in resource estimates.

3.17. Since the volume, weight and moisture content of the ore are the main parameters used in the calculation of the deposit's reserves, this property should be determined for each natural type of ore.

The bulk density of high-density ore is determined from the ore sample, and the bulk density of sparse, cracked, porous ore is determined from the sample coated with candle oil. The volume weight can also be determined by the absorption of gamma radiation, in which case it must be confirmed by control measurements. Moisture in the ore, which determines the volume by weight, is determined together. The mineral composition of the sample was studied to determine its volume, weight and moisture.

The volumetric weight determined by laboratory measurements shall be verified and confirmed by the value of the volumetric mass determined by rock mass sampling.

Based on the results of the study of the chemical composition, mineral composition, texture-structural features and physical properties of the ore, natural types of ore will be identified, and the type of production (technology) for selective mining and separate processing of ore will be planned in advance.

Based on the results of technological research conducted on all types of ore at the deposit, a final distinction will be made between production (technological) types and ore grades.

Four. Study of ore technological characteristics

4.1. Ore technological properties are studied in laboratory and semi-industrial conditions, mineralogical-technological, low-tech, enlarged laboratory and semi-industrial samples. The use of laboratory-confirmed analogues is permitted if there is experience in the processing of easily concentrated ores. For heavy and new types of ore to be enriched, in the absence of experience in the enrichment of such types of ore, a special program will be conducted to study the ore technology in consultation with stakeholders.

4.2. During the technology test, the possibility of pre-processing the extracted ore and sorting and sorting the coarse-grained ore into the packaging in which it is transported, as well as radiometrically sorting the ore with a high fraction yield of [(-200)-(+20)] mm. In the case of a positive result, it is necessary to identify the types of technologies that can be extracted or to prove the possibility of bulk processing of ore. Further deep ore beneficiation methods have been studied to ensure that the pre-processing stage is economically viable and feasible in the overall technological scheme.

4.3. In order to differentiate the types of ore technology, geological-technological mapping and sampling grids are selected depending on the number of natural types of ore and the frequency and interruptions detected.

All types of ore are determined by mineralogical-technological and reduced technology samples. Based on the test results, the geological-technological types of the deposit ore will be distinguished and geological-technological drawings, plans and sections will be prepared.

Laboratory and enlarged laboratory samples will be used to study all types of ore production (technology), to select the optimal ore processing technology scheme, and to determine the main parameters of the processing technology and products. At the same time, the optimal degree (size) of crushing the ore will be determined and the possibility of extracting the least amount of waste, contaminants, the lowest content of minerals in the tailings, and the maximum amount of minerals will be studied.

Semi-industrial technology samples are used to check the concentrator technology scheme and to clarify the ore concentration parameters set in the laboratory technology samples. The specialized technology testing organization shall develop the semi-production technology in cooperation with the subsoil user and carry out the program in accordance with the project (contract) organization. Technological sampling shall be carried out in accordance with the relevant instructions and a report shall be kept.

Enlarged laboratory and semi-industrial technology samples will be able to represent the ore, in terms of chemical and mineral composition, structure-texture, sharpness, physical and other properties, will represent the average performance of the production (technological) ore. The probability of an increase in the content of the plant is considered. The particle composition of the specimen shall be appropriate to the particle size of the rock obtained by the selected mining regime.

4.4. The study of industrial products by primary or basic ore or radiometric separation and screening uses technological mineralogy methods, oxidation states, mineral composition, structural and textural properties, physical and chemical properties of minerals and mineral complexes, and the degree of sharpness of these properties. Sieve and gravity analysis of the washed ore group, washing sludge and magnetic analysis of small particles will determine the quality of the ore grinding, the level of mineral phase separation and the degree of ore washing. Concentrator technology scheme is selected and the number of crushing-grinding stages and the amount of grinding (granules) are determinted. The method of enrichment is determined and the content of ancillary components in the concentrate and industrial products are explained.

4.5. The technological characteristics of lithium and caesium ore deposits depending on the mineral composition of the ore, the amount of ore mineral particles or their accumulation, texture-structural features, and the content of Li_2O and Cs_2O in the ore.

The main purpose of lithium ore beneficiation is to produce lithium products, which include carbonates, sulfates, chlorites, hydroxides, and lithium nitrate, and to produce metallic lithiums and commodities. All ores will be enriched to produce a commodity product.

The quality of the concentrate shall be regulated in each case by an agreement between the miner and the metallurgical plant or in accordance with applicable standards and specifications. Chemical treatment of lithium-caesium ore uses methods such as sulfuric acid, sulfate (heating with potassium sulfate), and lime (lime-chloride).

In production, lithium ore is enriched in the following ways. These include:

- manual separation of large crystals (+25 mm) of spodumene, petalite and pollucite or by simple enrichment;
- In the case of spodumene ores (in the absence of other associated minerals such as albite, fluorite, calcite, mica, etc.) thermal enrichment is used.

Granules of 50-20 mm to 0.2-0.3 mm size are incinerated at 1000-1200°C for 1-2 hours, cooled sharply and crushed to produce lithium concentrate;

- The following methods of flotation of spodumene containing quartz, mica, feldspar and sometimes iron oxide, beryllium and other minerals are used.
   1. Direct flotation of spodumene: In fatty acids and their soapy foam products, the alkaline medium is mixed with 1-3 kg/t of caustic soda.

2. Rotational flotation: In an alkaline environment, the cation collector is used as a spodumene suppressant with lime and dextrin. Quartz and feldspar wastes are mixed with melting acid during flotation in quartz suppressors and feldspar cation collectors. If spodumene concentrate contains a mixture of iron oxide, it is washed with soluble acid and dissolved. Then sodium salt of resin acid and pine oil can be added to remove the iron-containing minerals in the foamed product.
3. Collective flotation: Collective flotation of spodumene and muscovite uses muscovite concentrate with a cation collector in a weakly alkaline environment from the collective after the addition of sulfuric acid. Cation collectors can extract feldspar from collective flotation wastes and after the addition of smelting acid.

• Fine-grained lithium ore, especially spodumene ore with a 1-1.2% Li_2O content, can be enriched by thermal, flotation, magnetic separation, or heavy suspension solutions. Prior to flotation, empty rock is removed using a heavy suspension solution. The flotation method is the main method of concentrating lithium and complex ores and can be direct, reverse or combined. Lithium concentrate has a lithium oxide content of 7 to 9%.

For the processing of composite ores, this method is used in combination with a combined scheme, and in some cases additional magnetic classification and gravity methods are used.

The average grade of lithium ore used is 0.7 to 3% lithium oxide. Lithium concentrates of various qualities are used: spodumene (4.5-6.0%, 6.78% Li_2O), lepidolite (3-4%, 5% Li_2O), petalite (2.5-3.5% Li_2O), amblygonite (7.0-8.0%, 9% Li_2O) concentrates and the content of spodumene concentrate Li_2O shall not be less than 4.0% according to the current standard.

The main method of concentrating caesium ore is direct and reverse flotation. Processing of ores containing caesium-biotite requires more time and complex technology than pollucite. Processing uses flotation methods combined with chemical-metallurgical (cyclone-extraction, sulfuric acid leaching) processes.

The lithium ore beneficiation scheme is shown in Annex 2.

With the introduction of radiometric classification, the technical and economic performance of all types of ore processing is improving.

4.6. The results of the study will confirm the correctness of the geological-technological classification of the ore (if necessary, the geological-technological map will be reinterpreted or developed). The mineral composition and chemical composition of the primary ore and concentrated products were determined, and the washing, crushing and grinding parameters and the required grinding steps were determined; Primary ore sieve analysis and concentrator product parameters, bulk density and primary ore moisture, concentrated product data, and processing technology parameters were determined. In the case of radiometric concentrators - concentrate yield, content of lithium, caesium and related components in industrial products and wastes, their separation and concentration coefficient;

Gravity, magnetic classification and flotation processes - yield of concentrate, its quality (lithium, caesium and other by-products, content of toxic impurities), as well as concentrate processing methods, separate separation of lithium, caesium and other minerals, their final separation (end- to-end extraction), the amount of reagent used, the amount and nature of the product to be sent to the waste storage facility (particle composition, residual content of the reagent), and the decontamination of industrial water. The reliability of the results of the semi-industrial test shall be evaluated on the basis of technological and commodity calculations. The difference in weight of the metals in these residues shall not exceed 10% and shall be distributed proportionally by the mass of the metal in the concentrate and waste.

Processing parameters can be compared with those of modern concentrators and lithium, caesium ore and concentrate processing plants.

4.7. The study of the ancillary components in the ore will be carried out in accordance with the “Guidelines for a comprehensive study of the mineral deposit and the calculation of the resources of the ancillary components”. It will also use the “Рекомендация по комплексному изучению месторождений и подсчету запасов попутных полезных ископаемых и компонентов” recommendation developed by Russia in 2007. As for the by-products, their form in the ore, the balance of distribution in the ore processing and concentrate, and the appropriate economic conditions under which they can be distinguished shall be determined.

The possibility of recycling industrial wastewater and wastewater in accordance with the proposed technology scheme should be investigated; recommendations should include recycling sludge as compost and treatment of wastewater from the plant.

Five. Studies of hydrogeology, engineering-geology, geoecology and other natural conditions of deposit

5.1. The hydrogeological study of the deposit has studied the main aquifers that may be flooded, identified areas and zones with high water content, and resolved the use and disposal of mine water.

Aquifer thickness, lithological composition, collector types, feeding conditions, relationship between aquifers and surface water, location of groundwater level and other parameters are determined. The feasibility study identifies the amount of water that may be infiltrated during the planned excavation and provides recommendations for groundwater protection. The following surveys were conducted and evaluated by hydrogeological professionals (organizations, LLCs, individuals). These include:

- For hydrogeological purposes, boreholes were drilled and pumping tests were performed to determine the hydrogeological parameters of the aquifer.
- At the end of dewatering, groundwater samples were taken to determine the chemical composition, bacteriological status, corrosivity of concrete, metals, polymers, and beneficial and toxic impurities in the water. Determine the chemical composition of the mine water and wastewater from the mined deposit.
- Assess the potential impact of the mine water on the groundwater around the deposit, whether the mine water can be used for water supply or whether the mineral resources contained in the water can be identified.
- Make recommendations on whether further special studies are required and assess the environmental impact of the water being removed from the mine.
- Provides advice on possible sources of drinking and domestic water supply for future mining and processing industries.

In the case of mine drainage, water resources will be assessed in advance using appropriate methods and techniques. The hydrogeological study will provide the necessary recommendations for the development of the mine project. These include methods for drying geological blocks, drainage systems, how to drain mine water, water supply sources and environmental protection.

5.2. The geological survey to be carried out during the exploration of the deposit is intended to provide information necessary for the development of the mining project and to ensure the safety of the excavations.

The engineering-geological survey of the deposit shall be carried out by a qualified engineering-geological specialist in accordance with the approved instructions and recommendations.

Engineering and geological studies show that the strength of ore, bedrock and sediment is the physical and mechanical properties of natural habitats and water-saturated conditions; Engineering-geological features of the deposit rocks were studied. Their anisotropy, rock composition, cracking, tectonic damage, texture features, karsticity, weathering, and modern geological processes that may complicate the mining of the deposit were studied.

Lithium and caesium deposits are usually strong and brittle granite, pegmatite, etc. Particular attention should be paid to rock fractures, fractured zones, thickness, fracture quality of crushed rock and ore and crushing rate / degree, water flow that may occur along the elongation and collapse of fractures, and rock block formations.

In permafrost areas, the temperature regime, the location of the upper and lower boundaries of the permafrost, the range and depth of the melting / melting parts, changes in the physical properties of the rock during thawing, seasonal freezing and thawing of the rock, etc. were determined.

Engineering-geological surveys will provide information that can be used to make predictive assessments of the strength of underground excavation ceilings and open pit walls and to be used in the calculation of key open pit parameters.

In the case of underground and open pit mines operating in similar hydrogeological and engineering-geological conditions in the deposit area, these open pit and underground mine irrigation levels and engineering-geological information may be used in the exploration site parameters.

5.3. Lithium and caesium deposits are mined by open pit, underground and combined mining methods. In the case of combined mining, the boundaries of open pit mining shall be determined in terms of the maximum stripping coefficient and taking into account the balance of costs and costs of open pit and underground mining (minerals). The mining method depends on the mining and geological conditions of the ore bodies, the mining and technical characteristics, the ore mining scheme and is the basis for the feasibility study benchmarks.

5.4. The main purpose of geoecological research is to provide information necessary for the protection of the environment, including the geological environment, during the development of the deposit. Exploration and mining of lithium and caesium ores and processing of ores (lithium and caesium) produce a lot of fine dust. This dust contains BeO toxic compounds and lithium compounds are highly soluble, so lithium in water is harmful to the environment. Therefore, it is necessary to determine the background values of the state of the environment (radiation levels, surface and groundwater and air quality, soil, flora and fauna, etc.); to determine the physical and chemical impact on the environment during the construction of the planned facility (dust in the surrounding area, surface and groundwater, soil pollution from mining and industrial water, air pollution from emissions, etc.); the amount of natural resources to be used for industrial purposes (forest timber, water for technical purposes, main and auxiliary plants, stripping soil and host rock, non-standard ore stockpiles, etc.); the nature, intensity, level, hazards, sources, duration and boundaries of the zones of influence shall be assessed.

To address issues related to soil (biological) reclamation, soil thickness was determined, fluffy sediment agrochemical studies were conducted, stripping soil rock toxicity levels / grades were explained, and vegetation cover was studied. Measures should be taken to protect the subsoil, prevent environmental pollution, and provide recommendations for soil reclamation.

5.5. A detailed study of hydrogeological, engineering-geological, geocryological, mining-geological and other natural conditions will provide the information needed to develop a mining project. If the hydrogeological, engineering-geological and other natural conditions of the mining are very complex and require special works, the amount, time and procedure of the research works shall be agreed with the subsoil user and the project (contractor).

5.6. In the case of new deposits, it is mandatory to identify areas where no mineral deposits have been identified, where industrial and civilian housing can be built, and industrial waste and waste rock dumps can be constructed. The availability of construction materials in the area will be explored and the potential for the use of stripping soil rock as a construction material will be explored.

5.7. In the case of deposits, if sediments containing natural gas (methane, hydrogen sulfide, etc.) are identified, the pattern of changes in the composition and content of the gas should be studied at the site and depth.

5.8. Factors affecting human health need to be identified (risk of lung disease, high levels of radiation, geothermal conditions, etc.).

5.9. Other minerals: In the case of independent accumulation of other types of minerals in the deposit-bearing rocks and sediments, research work will be carried out to determine their production value and potential areas for use will be identified.

Six. Reserve estimation and resource evaluation

6.1. Reserves of lithium and caesium deposits shall be calculated and classified in accordance with the "Mineral resources, deposit reserve classification and instructions" approved by the Order No. 203 of the Minister of Mining and Heavy Industry on September 11, 2015.

6.2. Reserves are calculated in reserve blocks, and ore reserves do not exceed the annual capacity of the future mining plant. The ore bodies of the estimated blocks are defined as follows.

- At the same level of exploration, the amount of reserves and the quality of the ore were determined
- General/similar geological formations, thickness and internal structure of ore bodies, mineral composition, ore technology properties and key quality parameters are similar or have little change
- The location element of the ore bodies belonging to the resource block is stable and located in a specific structural element (folding wing, fold fold lock section, tectonic block limited by continuous cracks).
- Mining technical conditions are generally the same

Limitation of the resource block shall be determined by the excavation horizons or boreholes along the fall of the ore bodies, taking into account the order of preparation of the resource for operation.

If it is not possible to determine/surround (geometrize) the physical, industrial (technological) types of ore in the resource block and the distribution of ore grades, their evaluation can be done statistically.

6.3. Reserves are calculated taking into account additional conditions that reflect the characteristics of lithium and caesium ore deposits. These include:

Certain (A) grade reserves are calculated only for lithium ore deposits, based on exploration and mining data. This includes reserves of blocks that meet the requirements for resource classification, have been explored, prepared or are ready for extraction.

Actual (B) grade reserves are considered to be Group II lithium ore deposits only during exploration. This category includes reserves that meet the requirements for the classification of the actual grade by the degree of exploration and are identified in any part of the ore body or in the detailed exploration of the deposit.

The range of actual (B) grade resources is limited by exploratory excavations (excavations, boreholes), without extrapolation. It is determined on the basis of sufficient information that can represent the quality of the ore within the real (B) grade resource range and the basic geological characteristics of the ore bodies. If it is not possible to geometrically model the quality and quantity of industrial ore within a block belonging to this grade of resource, it can be estimated statistically.

If the amount of ore in the deposit is determined using the mineralization coefficient, the mineralization coefficient of the blocks belonging to the proven resource category is higher than the average value of the deposit. They may include parts that have been studied to the extent that they can be evaluated for selective extraction.

Actual (B) grade reserves in caesium deposits are calculated based on additional exploration, exploration and mining data in accordance with the requirements for the classification of this grade.

Potential (C) grade reserves shall be calculated in the dense section of the grid to meet the requirements of this class of resources. The reliability of the information in the estimated (C) grade reserve is confirmed by the results of the detailed exploration of the deposit or by the mining data of the deposit in use. Where geometric modeling of ore bodies in highly complex deposits is not possible, the quality and quantity of production ore and resources in the resource block can be assessed statistically. In doing so, the study of the main features of the internal structure (formation) of the deposit took into account the distribution patterns and ore saturation of the mineralized parts that meet the standard requirements.

The range of available (C) grade resources is limited to exploration excavations and can be surrounded by large, continuous ore bodies with limited extrapolation based on geology based on ore quality, thickness and shape characteristics of the ore bodies.

Estimates of discovered (P_1) resources for specific ore bodies (can be calculated statistically within a single boundary if geometric modeling of ore bodies is not possible); or geophysical surveys, geological-structural conditions, and studies of changes in the thickness of ore bodies are used to estimate the content of lithium and caesium in ore bodies confirmed by individual sections.

6.4. Li-Cs pegmatite deposits are estimated at the geological boundary of the pegmatite body.

6.5. Reserves are classified separately by mining method (open pit, horizontal shaft, mine), type of ore production (technological) and variety, and their economic significance according to the degree of exploration.

Additional indicators can be used to classify/distinguish mineral resources into resource categories (B, C, P), such as the accuracy, reliability, quantitative and probabilistic/feasibility assessments that define the key resource estimates. If it is not possible to determine the proportions of different types and grades of ore production by their range and boundaries, they shall be determined statistically.

An unbalanced (economically viable) resource/ore is also estimated, taking into account whether it is possible to keep the ore in the subsoil until further mining, or whether it is economically feasible to properly mine and store it for future use (storage). In the case of a guarantee, the resource is calculated and included in the resource.

The calculation of off-balance sheet resources should be based on the reasons (economic, technological, hydrogeological, ecological, etc.) included in this group.

Ore reserves (balanced and unbalanced) are calculated from dry ore and have moisture content. Moisture-rich porous ore reserves are calculated from raw ore.

6.7. Conventional methods (geological blocks, geological sections, etc.) are used to identify specimens with extremely high levels of lithium and caesium, which are analyzed for their impact on the average content of exploration sections and resource blocks and, if necessary, their impact is limited. It is advisable to separate the parts of the ore body with very high grade and very thick ore into separate resource blocks for detailed exploration.

Comparative results from exploration and production data can be used to determine the level of ultra-high grades in the mined deposits and how to change their values (especially in the case of lithium and caesium, compare the distribution characteristics of the sample distribution with the content of the compacted mesh).

6.8. Depending on the level of exploration, the ore reserves of the extracted deposits will be classified and calculated according to the level of exploration.

6.9. Ore reserves in large reservoirs, rivers, residential areas, buildings, agricultural facilities, protected areas, and protected areas of natural, historical, and cultural sites shall be calculated and included in accordance with approved standards.

6.10. In order to monitor the full development of previously registered reserves in the mined deposits and to compare the newly calculated resource credentials with the location conditions, shape, thickness, internal structure of ore bodies and mineral content determined during exploration and resource extraction in accordance with established procedures. is. For comparison materials:

- boundaries of resources previously registered and deducted by a state expert body (including mined and retained reserves)
- Unapproved excluded resources
- boundaries of reserve areas
- Displays resource boundaries, such as resource data recorded in the State Reserve Balance Sheet (including the balance of reserves previously recorded in the MRPC).
- Resource flow chart for each ore grade by ore body and at the deposit level
- range of mined resources with ore quality indicators
- changes in resources recorded by completion exploration
- wastes during mining and transportation
- product output
- tailings from ore processing, etc.

The results of the comparison are plotted graphically, along with changes in perceptions of the deposit's geological conditions.

The results of geological surveying can be used to compare exploration and production data if the exploration data are confirmed in their entirety by mining, or if the small discrepancies do not affect the technical and economic performance of the mining industry.

At the deposit level, in the opinion of the subsoil user, if the reserves or ore quality approved by the authorities are not confirmed during mining, it is necessary to include previously established parameters and maintenance coefficients in the reserves and evaluate the confidence of results.

As a result of the comparison, changes in resource estimates (reserves estimated, ore body thickness, mineralization coefficient, mineral content, volume weight, etc.) discussed at the MRPC meeting should be determined, and reserves and ore quality changed as a result of completed exploration and production and the reason for the change shall be explained.

6.11. In resource estimation, geostatistical modeling is widely used to study, estimate, and estimate error variations in spatial distribution using the kriging method (mineral content, ore section thickness, metropocenter).

Using the Kriging method, the quantity and quality of primary exploration data should be adjusted to the specifics of the geological formation of the deposit (distribution patterns, trends and anisotropic properties of resource estimates, structural boundary effects, quality and structure of experimental variograms, search ellipsoid dimensions) which is effective for analyzing and modeling primary data. Using the Kriging method, the number and density of exploration sections are sufficient to form an optimal interpolation equation (no less than a dozen exploration sections in two-dimensional modeling, and hundreds of samples in three-dimensional modeling). The spatial variability is suitable for the detailed study of the deposit.

The calculation of the variogram is performed by the cross-section of the ore body (by vein type), the main sample, the length of the sample by the height of the open pit bench (stockwork, very thick, large mineralized zone), if vertical mineralization changes cannot be studied.

When constructing a block geostatistical model to estimate the deposit's reserves, the unit should be selected with the maximum and minimum possible exploration grid density for the proposed mining technology (with the sides of the unit being less than 1/4 and 1/8 of the average exploration grid density). The results of resource estimates can be presented in two ways. These include:

- To calculate blocks of equal size and with the same lattice, compile a table of calculated quantities for all unit blocks, including the value of the Kriging variance.
- For the calculation of large geological blocks that have created their own geometric shapes, each block is connected in space and a list of samples included in the impact zone is made.

All quantitative data/data (sampling data, sample and ore cross-section coordinates, analysis of structural / structural variograms) can be monitored in the simplest and most commonly used formats (e.g MS Excel, Access, Surpac, Micromine, LeapFrog, etc.). Symmetry change models, trends, and variograms are presented in descriptive/visual and analytical form.

The geostatistical method of resource estimation allows to determine the average grade optimally without the use of special methods to reduce the impact of high-grade specimens on resource blocks, ore bodies and deposits. allows for optimal selection. Geostatically calculated reserves can be tested in this way and are subject to the specifics of the geological formation of the deposit. The results of geostatistical modeling and its evaluation in the areas that are representative of the deposit are compared or monitored with the results of traditional resource estimates.

6.12. If the resource estimate is to be calculated by a computer program, the primary data should be (coordinates of exploration excavations, inclinometer data, lithological-stratigraphic boundaries, scope notes, sampling results, etc.); intermediate calculations and construction results (list of ore segments separated according to the standard, geological sections and plans of industrial mineralization / ore boundaries, projections of ore bodies in the horizontal and vertical planes, reserve blocks, bench and section calculation parameters / parameters) and resource The summary results of the calculations shall be viewed, verified and corrected. All documents, as well as computer-generated graphics and drawings, contain the structure, composition, format, etc., that are placed in this type of document (for writing and writing resource reports), requirements are met.

6.13. Reserves of ancillary minerals and mineral resources shall be calculated in accordance with established procedures. “Рекомендация по комплексному изучению месторождений и подсчету запасов попутных полезных ископаемых и компонентов, 2007” recommendation by Russia can be used.

6.14. The resource estimate report will be prepared in accordance with the “Procedure for mineral exploration, prospecting and mining activities” approved by the Order A/20 of the Minister of Mining and Heavy Industry of Mongolia in 2018 and will be discussed at the MRPC meeting.

Seven. Study degree of deposit

7.1. According to the Annex of the “Resource Classification” approved by the Minister of Mining and Heavy Industry of Mongolia (Order No. 203) dated September 11, 2015, deposits (or parts thereof) may be classified as explored or explored according to their level of exploration. requirements for estimated reserves and resources.

The level of exploration of the assessed deposits will be assessed on the basis of whether there is a need to continue exploration work on the sites, and the level of exploration of the explored deposits will be assessed on the basis of their readiness for mining.

7.2. In the case of lithium and caesium deposits that have been explored or evaluated, the production value, the appropriateness of the exploration phase, the overall size of the deposit, and the most promising areas for exploration and production have been identified.

Valuation of newly discovered deposits will be based on a temporary feasibility study developed in the results report, which will be sufficient to conduct a preliminary geological and economic assessment of the deposit and ore sections.

The assessed deposit is classified as (P_1) and the geological resources of some areas are classified as possible (C).

Mining methods, systems, and potential mining assumptions based on similar projects; technological scheme of mining with full use of raw materials; potential yield and quality of marketable products based on laboratory sample research; plant construction costs; The cost of goods sold and other economic indicators are determined and aggregated based on the status of similar projects.

The importance of lithium and caesium ore production is assessed in advance based on the water supply and potential sources of water supply for the mining and existing (exploration) and exploration facilities.

The environmental impact of the development of the deposit will be studied and assessed.

The shape of the ore bodies, the composition of the ore material, the development of the ore processing technology scheme, and the processing of the ore at the assessed deposit (section) can be studied in detail through experimental-production processing (exploration) studies (EPPS).

The EPPS shall be conducted for a period of not more than 3 years, as part of the exploration phase to estimate the results, with the approval of the Mining Supervision Authority, on the most common or general characteristics of the ore bodies capable of representing most of the ore bodies. The amount and duration of the EPPS shall be agreed with the state specialized inspection bodies in charge of ecology, technology and nuclear issues. In each case where it is necessary to conduct an EPPS, its purpose and objectives shall be identified.

The EPPS will be conducted to clarify the geological features of the ore body (internal structure and deformation), mining and geological and mining conditions, and mining and processing technologies (natural ore types and technologies, and the relationship between them). These problems can only be solved by deep excavations of ore bodies.

In the case of large and very large deposits, it is advisable to conduct a EPPS in a small-scale concentrator in order to test and refine or improve the developed technological scheme before the construction of the main (processing) plant.

7.3. It is necessary to have enough information to develop a feasibility study to resolve the conditions and procedures for putting the explored deposit into production, as well as the quality and quantity of resources, ore technology characteristics, hydrogeological and mining technical specifications for developing a mining project or upgrading the plant and ecological conditions have been fully explored by boreholes and excavations.

The explored deposits meet the following requirements at the research level. These include:

- It is possible to include most of the resources in the category corresponding to the complexity group of the geological formation of the deposit;
- A detailed study of the types of mineral production, the composition of substances and technological properties of ore varieties, the results of which will provide sufficient information to plan the optimal technology for the integrated processing of industrially important minerals; identify areas and areas where industrial waste can be used or the best options for storing or burying it;
- Mineral-bearing resources (stripping sediments and groundwater) that coexist with the ore have been adequately studied and evaluated to the extent that they can be classified as geological resources or resources on a case-by-case basis, their quantity and potential use;
- Thorough study of hydrogeology, engineering-geology, geocryology, mining-geological, ecological and other natural conditions, as well as mining projects to ensure the safety of mining operations and environmental protection legislation;
- Confidence in information on geological formations, condition, shape, quantity and quality of ore bodies should be verified by detailed work on formations that can fully represent the deposit, and the size of such areas should be determined in each case depending on the geological characteristics of the deposit;
- Assess the environmental impact of mining and make recommendations for mitigation and prevention;
- The benchmarks to be used in the resource estimate are at the level of trustworthiness, and the significance and scale of the deposit's production are determined on the basis of feasibility studies;

Appropriate ratios of reserves of different grades for the explored deposit will be determined by subsoil users and MRPC experts, taking into account the level of business risk.

In each case of full or partial extraction of P_1 grade reserves, MRPC experts (relevant professional experts) will make a decision in the form of recommendations based on the deposit resource estimates. In this case, the decisive factors are the geological characteristics of the ore bodies, the thickness of the ore bodies and the nature of the distribution of mineralization in them, the assessment of possible exploration errors (exploration methods, technical equipment, sampling, analysis), and experience in exploration and mining of similar deposits.

The explored deposits shall be deemed to have been prepared for mining for use after the provisions of this Recommendation have been complied with and the reserves have been duly registered.

Eight. Re-estimation and registration of deposit reserves

8.1. Recalculation and re-registration of the deposit at the initiative of the license holder (subsoil user) and the state administration and specialized inspection agencies in case of significant changes in the quality and quantity of the deposit resources and geological and economic assessment as a result of additional geological exploration and mining activities The work shall be performed in accordance with established procedures.

At the initiative of the licensee, the reserves will be recalculated and re-registered in the following cases, which will significantly impair the economic efficiency of the plant. These include:

- In the event that previously recorded ore reserves and/or ore quality are not confirmed;
- If the price of the product falls steadily and significantly (20% or more) while maintaining the cost level of production;
- Production requirements for mineral quality have changed;
- The total amount of reserves during exploration and production exploration and mining, the amount of unapproved reserves prepared and excluded, and the amount of reserves that could not be mined due to technical and economic reasons exceeded the established norms for deducting reserves from the balance of the mining industry (more than 20%) or decreased cases

Reserves shall be recalculated and re-registered at the initiative of the inspection and professional inspection body in the following cases, such as violation of the license holder's (state) interests, in particular unreasonable reduction of taxable income. These include:

- Reserves have increased/increased by 50% or more from previously recorded amounts;
- In the case of a significant and steady increase in world market prices for industrial products (increased by 50% or more above the standard price);
- New techniques and technologies have been developed and introduced to dramatically improve production economics;
- Ore and host rock include cases of unexplored mineral deposits and toxic impurities during deposit appraisal and production design.

The economic problems of production due to temporary reasons (difficulties in geological, technological, hydrogeological and mining-technical conditions, temporary decline in world commodity prices) will be resolved through the use of standard mechanisms, in which case reserves will not need to be recalculated and re-registered.

References

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Appendix 1

Indicators used to determine the complexity of the geological formation of a solid mineral deposit

The density of the exploration system and the exploration grid depends mainly on several natural factors: the location and structural-geological characteristics of the ore body (shape and stability of the ore body, boundary characteristics) and the distribution of minerals (mineral quality level of change in the ore body).

There are basic numerical values required for complex grouping of deposit/ore bodies. These include the mineralization coefficient (K_x), the coefficient of complexity of the deposit (q), the ore body thickness coefficient (V_m), and the content variability coefficient (V_a) (A.P. Prokofiev, 1973).

a. The mineralization coefficient *(K_x)* is used to differentiate between resource units of an interrupted mine. It is defined by the following formula:

$$K_x = \frac{\sum l_i}{L}$$

Here: l_i – linear dimensions of ore sections excavated and drilled, L – linear size of the total mineralized area determined by excavation and borehole.

b. The coefficient of complexity of the deposit *(q)* is determined by the following formula:

$$q = \frac{N_x}{N_x + N_{xг}}$$

Here: N_x – mineralization excavation and number of boreholes, $N_{xг}$ – number of unexamined excavations and boreholes.

c. The change in the thickness of the ore body is determined by the following formula:

$$V_m = \frac{\sigma_m}{\overline{m}}$$

Here: V_m – the ore body thickness coefficient, σ_m – ore body thickness dispersion, $\overline{m}$ – average thickness of ore body.

d. Changes in the content of a useful plant are determined by the following formula:

$$V_a = \frac{\sigma_a}{\overline{a}}$$

Here: V_a – the content variability coefficient, σ_a – the dispersion of the content of the useful plant, $\overline{a}$ – average content of profitable components.

Possible maximum values for the complexity of ore bodies of groups I, II, III and IV deposits (Table-6)

Numerical values of changes in basic properties of mineralization

Table-6

Ore groups	Complex of geological formations of the deposit status indicators			
	Ore body shape			Content
	K_p	q	V_m, %	V_C, %
Group I	0,9–1,0	0,8–0,9	< 40	< 40
Group II	0,7–0,9	0,6–0,8	40–100	40–100
Group III	0,4–0,7	0,4–0,6	100–150	100–150
Group IV	< 0,4	< 0,4	> 150	> 150

The decision to classify a deposit shall be made taking into account the completeness of all geological information that reflects the maximum change in the shape of the ore body and the content of the mineral.

Appendix 2.

Lithium ore beneficiation scheme

Lithium ore beneficiation schemes use flotation and combined flotation of fine-grained lithium minerals in the processing plant and use direct and reverse flotation.

- For example, ore from the Hill City deposit is directly enriched by flotation. The ore contains 12-20% spodumene, 30-50% quartz, 20-40% feldspar and 2% mica. This scheme produces feldspar and mica. Add 0.3 kg/t NaOH to the mill, 1 kg/t NaOH and 200 g/t oleic acid and foaming agent to the main flotation. Liquid glass, Quebec, lactic acid and foaming agents are added for cleaning. Spodumene flotation of the Hill City deposit takes place in two purifications, with a total flotation time of 9 minutes.

The reagents are mixed with 90 g/t foaming agent, 0.25 kg/t H_2SO_4 flotation tailings solution, and 30 g/t oleic acid.

93-97% spodumene concentrate has 90.3% metal recovery, mica concentrate has 50-90% metal recovery, 90% fluorspar concentrate has 95% metal recovery and 88.5%.

- Rotational flotation scheme enriches spodumene ore at the Kings Mountain deposit in North Carolina. Ore contains 15-30% spodumene, 35-50% feldspar, 20-25% quartz, 3-5% mica, 5-7% other minerals (beryl, cassiterite, columbite, garnet, tourmaline, monazite, pyrrhotite, pyrite, etc.) are contained.

Sulfur leaching technology scheme

Appendix 3.

Some common minerals of lithium

1. Kunzite with quartz and albite crystals (pink spodumene $LiAl(Si_2O_6)$)

2. Lepidolite with quartz, albite and topaz crystals ($KLi_{1,5}Al_{2,5}Si_3O_{10}(F, OH)_2$)

3. Petalite crystals (LiAlSi4O10), Petalite vein of the Zavitinskoe deposit in Russia

4.Amblygonite (LiAlPO4(F, OH)), Kester deposit in Russia, East Yakutsk

5. Spodumene in pegmatite

6. Lepidolite

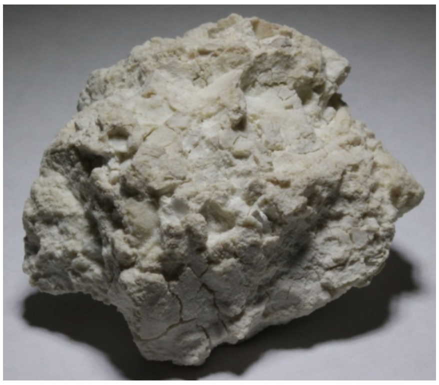
7. Hectorite- clay minerals (Hectorite (english), гекторит (russian))

$Na_{0.3}(Mg,Li)_3Si_4O_{10}(F,OH)_2*nH_2O$)

Hardness 1-2, Monocline, Smectite group

Liles Hectorite Mine, Thompson Valley, Arizona, USA

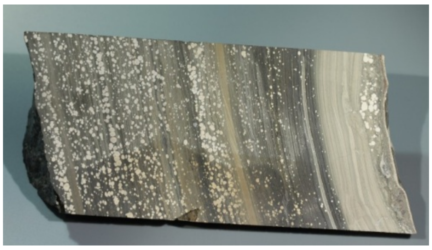
San Bernardino Company, Newberry Hectorite Mine, California, USA



USA, California, San Bernardino Company, Cady Mountain, Hectorite

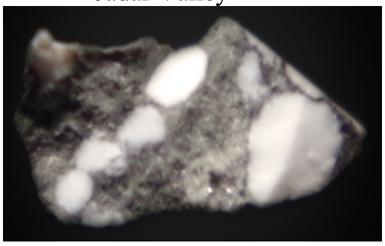
Liles Hectorite Mine, Thompson Valley, Arizona, USA

8. Jadarite (Jadarite (english), ядарит (russian))
$LiNaB_3SiO_7(OH)$



Serbia, Central Serbia, Makwa Province, Loznika, Jadar Valley

Serbia, Central Serbia, Makwa Province, Loznika, Jadar Valley



Serbia, Central Serbia, Makwa Province, Loznika, Jadar Valley

Serbia, Central Serbia, Makwa Province, Loznika, Jadar Valley

Appendix 4.

Brief information on lithium (Li-Be-Cs-Rb-Ta-Sn) deposits discovered in Mongolia

Currently, there are two main deposits of lithium in Mongolia, Munkhtiin Tsagaan Durvuljin and Khukh Del, one deposit and several occurrences.

Mongolia's estimated lithium reserves are estimated at 203,000 tons, and the reserves of two lithium deposits have been registered by the Mineral resources and Petroleum Authority of Mongolia.

The Khukh Del deposit in Dundgovi aimag has proven reserves of 37.7 thousand tons, and large reserves of 151.3 thousand tons. Lithium ore reserves total 122.3 thousand tons, according to MRPAM.

The actual reserves of the Munkhtiin Tsagaan Durvuljin deposit in Dundgovi aimag are estimated at 14,575 thousand tons. Lithium ore reserves are 2,260,000. tons.

Munkhtiin Tsagaan Durvuljin pegmatite deposit

It is located in Bayanjargalan soum of Dundgovi aimag and Shiveegobi soum of Govisumber aimag.

The Munkhtiin Tsagaan Durvuljin rare metal deposit is a marble limestone of the Neoproterozoic Oortsog formation, a pegmatite vein containing rare metals along the tectonic faults at the boundary of the deep rocks of the Kherlen Formation of the Mid-Late Cambrian.

The metasomatite and pegmatite bodies in the form of veins and lenses are small in size, unstable in thickness, and have an uneven distribution of useful deposits.

Pegmatite veins include quartz, plagioclase, lepidolite, K-feldspar, calcite, fluorspar, lithium-containing mica, and iron-containing lithium sericite; secondary minerals include quartz, sericite, garnet, pelite, and epidote; Minerals such as sphene and leukogens have been identified as accessories.

The production of lithium, rubidium, and caesium has been determined in pegmatite veins, and no other minerals have been identified.

The geological reserves of the deposit are estimated as real and potential (B+C) for 2,263,791.4 tons of ore with 0.62% average grade Li_2O 14 504.49 tons, 0.01% average grade Rb_2O 4 250.82 tons, 0.03% average grade Cs_2O 586.46 (P_1) - was estimated at 3,291,248 tons.

Khukh del lithium clay deposit

Located in Ulziit soum of Dundgovi aimag. This deposit is the first lithium deposit of sedimentary origin in Mongolia and also contains uranium mineralization.

The mineralization of the Khukh Del deposit occurred at the same time as the accumulation of sediments of the Middle-Upper Jurassic Lake and marine sediments. Lithium mineralization is weakly and strongly pyriticized, carbonated, and weakly fluorinated, and the ore body near the surface is defined by a layer-like argillite thickness. The boundaries of these are not clear and are determined only by sampling.

Ore minerals include hematite, hydrogite, limonite, bornite, malatite, goethite, pyrite, pyrrhotite, chalcopyrite and arsenopyrite. Also available as fluorite, rutile, barite-calcite, apatite, sphalerite, zircon, monazite, tourmaline, barite, gypsum and ilmenite as accessories.

The deposit has 443.6 million tons of ore with an average grade of 0.157% lithium and 644.3 thousand tons of ore with an average grade of 0.153% lithium.

Brief information on deposits discovered in other countries
Zavitinskoye pegmatite deposit (Li-Ta) in Russia

Lithium ore was mined at the Transbaikalian Mining Corporation in 1942-1995, located in the Shilkinsky District of the Russian Federation.

Adjacent to the ore body are leukogranite, non-ore pegmatite bodies, and low-grade pegmatite bodies of rare metals (Be, Sn).

The internal structure of the ore bodies of the Zavitinskoye deposit is very complex. These include:

1. Fine-grained quartz-albite (white albite)
2. Fine-grained spodumene-quartz-albite (gray albite)
3. Quartz - (+ spodumene) -albite, granite
4. Roughly irregular, large crystalline spodumene - (+ calcite, muscovite) -quartz-albite (pegmatite) bodies sometimes contain blocks of quartz-spodumene
5. Medium and coarse-grained quartz-muscovite (greisen)

Spodumene - (+ calcite, muscovite) -quartz-albite bodies have 4 times higher lithium content than spodumene-quartz-albite (gray albite) bodies. In the quartz-spodumene section, the lithium content reaches 3.9% by mass.

Minerals: spodumene types such as hyddenite, sesame, green and pink tourmaline (elbait), petalite.

Alakhinskoe spodument granite deposit of Russia (Li, Ta)

It is located 1.5 km from the source of the Karaalahi River in the western part of the Kosh-Agach district of the Altai Republic of Russia, near the border with Kazakhstan.

The lower Jurassic Alakhinsky granite shaft, which cuts the granite of the Rakhmanovsky complex in Devon, consists of spodumene granite-porphyry and muscovite-spodumene tarantulite leukogranite. Two ore-bearing bodies have been identified, which are irregularly shaped, 0.3 km^2 “Главное” and 0.2 km^2 “Малое”.

The spodument granite massif covers an area of approximately 0.4 km^2. At the apex of this massif, surrounded by a cut-off content of 0.007% Ta_2O_5, a dome-convex-shaped ore body was identified.

Lithium minerals are usually spodumene, but petalite and montebrazite are also found. Of the tantalum minerals, small amounts of tantalite, microlite and pollucite have been identified. Lithium content in the ore, on average Li_2O 0.71%.

One of the largest lithium deposits in Siberia is the Alakhinskoye deposit. Estimated reserves: 68 million tons of ore with an average grade of 5% spodumene in the ore, valued at approximately 3.4 million tons of spodumene concentrate or 448,000 tons of Li_2O.

In addition to spodumene, tantalum, mica, and feldspar concentrates can be extracted from ore. Main ore minerals: spodumene, tantalite, pollucite, mica, feldspar. Average mineral content of ore bodies (%): lithium 0.8, tantalum 0.012, niobium 0.015, rubidium 0.12, caesium 0.026. The tantalum deposit of the deposit was initially approved at a depth of 50 m from the “Main” shaft.

Bernick Lake (Tanko) pegmatite deposit in Canada (Li-Cs, Sn, Be)

A large plagioamphybiolite massif with extensive pegmatite development in the eastern part of the Canadian province of Manitoba. The plagioamphybolyte massif contains pegmatite, and the main body of the “Главное” pegmatite is located 900-1000 m to the east of the granite massif, and the eastern boundary of the granite massif appears to be located above the massif because it slopes below the amphibolite.

The " Главное " pegmatite body is elliptical in shape, elongated along the latitude, sloping to the north at a slope of about 20°. The central part of the ore body is in the form of a “saddle” that is sunk to the left and right at 10-30°. The length of the vein is 1000-1100m and the width is 460m. The maximum body thickness is 85m.

Pegmatite is a giant crystalline. In aggregates consisting of fine-grained spodumene, albite, quartz, and muscovite, the spodumene crystals are up to 1 m long and the microcline-pertite crystals are up to 2.5 m long. Sometimes albite or spodumen-enriched strips have alternating textures. The upper zone is 4.5m to 28m thick, and the lower zone is a few centimeters to 10-12m thick.

The central intermediate zone consists of microcline-pertite, albite and quartz. The thickness reaches 45 m at the widest part. This zone moves slowly and sometimes abruptly to other zones. Major minerals: lithium muscovite, beryllium, spodumene, vodjinite, cassiterite, microlite, tantalite, apatite, trifillin-lithiophyllite, tapiolite, rarely arsenic bismuth, bismuth.

The pollucite zone consists almost entirely of pollucite and is represented by three mesh-shaped, 1.2-13.7 m thick bodies. These bodies are composed of dense aggregates of pollucite, sometimes with quartz, small crystalline spodumene, and lepidolite veins.

The lepidolyte zone consists of two plate-like bodies and several small mesenteric bodies. Large crystalline particles range in thickness from 1.5 m to 11.6 m. Lepidolite is a dense, fine-grained scaly. Beryllium, tantalite, cassiterite, garnet, spodumene and rhodochrosite are found in this zone.

The Bernick-Lake “Главное” pegmatite body contains a wide range of minerals, including quartz, albite, pollucite, and lepidolite.

Another feature of the deposit is that the ore minerals are unevenly distributed in some areas and have different formations in different parts of the body.

Greenbush pegmatite deposit in Australia (Li-Cs-Ta)

Talison Lithium's lithium mine and refinery are located in the south of Greenbush, Western Australia.

The ore bodies of the Greenbush deposit are Li-Cs-Ta mineralized pegmatites and are arranged in series along the northwest elongated regional faults. The largest zone of pegmatite is 3 km long and 300 m wide, with several small pegmatite branches branched from the main ore body and lateral ore bodies. Pegmatites are mesh-shaped and have mineral belts along the fall and elongation. The lithium zone is more than 2 km long and is rich in spodumene up to 50% of the rock, which is very different from other rare metal pegmatite bodies.

Greenbush lithium ore-spodumene is mined in open pits from un weathered, unaltered parts.

It has 1.5 million tons of Li_2O reserves, and 3.31% Li_2O is estimated at 35.5 million tons and 1.1% Li_2O is estimated at 190.8 million tons. Due to the very low iron oxide content in pegmatite (<0.1%), the ore is considered the most suitable for use in the production of lithium glass and ceramics.

The company exports 6% Li_2O spodumene concentrate to China for the production of lithium chemicals.

China has many large lake salt deposits. The Tibetan consortium owns the right to mine the Jabue Salt Lake in Tibet. Dongtai Salt Lake (also known as East Taijinar) is a joint venture between Qinghai Salt Lake Industry Group and Western Mining Group.

The salts of these lakes are very complex and are mined in very small quantities compared to the lakes' reserves.

La Ventana deposit (Li) in Sonoram Mexico is estimated to contain 60 million tonnes of lithium clay with a grade of 3000ppm Li and more than 180,000 tonnes of lithium.

Jadar Valley deposit (B-Li) in Serbia is located in the Jadar Valley, 100 km from Belgrade, Serbia. In 1998, exploration identified three vertical zones of boron and lithium in the lake's alkaline sediments and evaporated deposits, known as jadarite. The bedrock consists of three overlapping layers.

The thickest and lowest zone is approximately 4.5 km^2 and contains 114.6 million tonnes of 1.8% Li and 13.1% B_2O_3. In terms of location, this zone is located at a depth of 300 to 600 meters above the surface, and the thickness of the ore bodies varies from 9 to 20 m. The deposit is estimated to contain 6.4 million tonnes of boric acid and 1.4 million tonnes of lithium carbonate, based on experimental work, turnover and industrial waste.

Jadarite contains 7.3% Li_2O.

Some words and phrases translated from Russian

Russian	Mongolian	Russian	Mongolian
Естественный выход, обнажение	үндсэн гарш, гарш	Горные выработки, пересекающие рудное тело	хүдрийн биетийг огтолсон эсвэл нэвтэрсэн уулын малталтууд
Естественное залегание	байгалийн хэвтэш, байгалийн гарш, гарш	Геофизическое опробование	геофизикийн хэмжилт /сорьцлолт дээжлэлт/
Восстающий	далд малталт дахь босоо малталт/нэвтрэлт	Оконтуривание	хил зааг, хүрээ
Забой	мөргөцөг, ул, хажуу хана (малталт, цооног)	Целики	Тулгуур багана /хүдрийн биетийн цуллаг/
Забой скважин	цооногийн ул	Общность	Нийтлэг, ерөнхий төрх байдал
Блок	Блок		

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