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METHODICAL RECOMMENDATION APPLIED FOR CLASSIFICATION OF MINERAL RESOURCES AND CERTAIN TYPE DEPOSITS' RESERVES OF MONGOLIA

(ALUMINIUM)

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Disclaimer

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

ALUMINIUM

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This recommendation is designed for employees of enterprises and organizations operating in the sector of subsoil use, regardless of their departmental affiliation (or subordination) and ownership.

The application of the "METHODICAL RECOMMENDATION…" will be useful to be provided geological information, the completeness and quality of which are sufficient to make decisions on further exploration or on the involvement of reserves of explored deposits in industrial development, as well as the design of new or reconstruction of existing enterprises for the extraction and processing of minerals.

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CONTENT

Introduction

The recommendation was produced in accordance to a number of provisions of relevant law, decrees and regulations as follows: "Regulations on Mineral prospecting and exploration activities" approved by order #A/20, 2018 by the Mining & Heavy Industry Minister, as well as a provision approved by a Mining Minister order #203, 2015, which specifies that "The present recommendation for classification of mineral resources and deposit reserves can be applicable to a mineral resource in compliance with any recommendations for a certain type of mineral on the basis of its characteristics".

The recommendations provide the practical assistance for entities who own exploration and mining licenses, geologists, prospectors, miners and aluminium ore mining organizations to compile a final report on reserve estimation, to have the estimated reserves registered to the state mineral resource register and update reserve data.

Aluminum, one of the industrial minerals, is widely used in metallurgy and non-metallurgy (metallic aluminum, bauxite, cement, sandpaper, refractories, etc.). It shows the consumption is not declining around the world, and demand is expected to increase.

Although tropical countries such as Africa (Guinea), South America (Brazil), Australia, Asia (Indonesia, Vietnam, India, and China) are dominated by bauxite with aluminum-rich laterite or gibbsite, it is believed that the Mongolia has a sufficient geological conditions (Zaitsev, 1981) for mineralization of bauxite, nepheline and alunite, in the ancient rocks which are main indrustrial types. For example, in the Alag-Uul diaspora bauxite with an Al_2O_3 content of up to 47%, as well as Uvurmaraat, Dushiin Gol, and Beltesiin Gol group deposits in the nepheline-containing alkaline magmatic rock massifs, and alunite-type mineralization has already been identified in many zones of volcanic systems with intensively developing hydrothermal metasomatite alteration. In addition, aluminum mineralization in the disten-sillimanite-andalusite (stavrolite, cordierite)-containing Proterozoic metamorphic rocks in the Alag Tekhtiin Uul district of Altai Mountains and Buteel mountain range, has not been fully explored. Researchers consider that this type of deposit forms when the sedimentary bauxite layer is affected by high-grade metamorphism and it is still been searching the mining technology of it.

The total reserves of the above three aluminum deposits in Mongolia are 130664.16 thousand tons by B+C category, and dozens of occurrences have been identified, as well as geological mapping and thematic studies have been revealed aluminum-rich rocks. Therefore, it is highly significant to have the methodological recommendation for prospecting, exploration, reserve estimation and resource assessment of aluminum mineralization.

One. Basic terms

1.1. This metal has a color of light grey and it melts at 660°C and boils at 2581.82°C. It is soft and ductile, has a density of 2.6989 g/cm^3, and hardness of 2.75. Aluminum is a metal that plays an important role in industry. In terms of production and consumption, it ranks second only to iron, and first among non-ferrous metals. This is directly related to its low density (2.7 g/cm3), high electrical conductivity, flexibility, corrosion resistance and widespread use in all technical fields.

1.2. It is widely used in aviation, automotive, construction, chemical and mechanical engineering, electrical industry and packaging industry. The most important consumer sectors are automobiles, construction (cement), and packaging (foil, cans). If we look at the structure of consumption, the share of production of durable products, such as cosmetics, beverage containers, packaging materials, exterior decoration, dishwashers, is growing steadily. The use of powdered aluminum to separate metallic and non-metallic elements from their oxygen compounds is increasing, while pure aluminum is widely used in the production of lead electrolytic capacitors, cryoelectronics, and semiconductors. Its consumption reaches 350-400 million tons per year.

1.3. Bauxite deposits are classified as large if they have reserves of more than 30 million tons, medium if they have reserves of 3–30 million tons, and small if they have reserves of up to 3 million tons. Based on Mongolian and regional studies, researchers have classified the size of aluminum deposits according to their genesis type into large, medium, and small categories, such as bauxite >50, 5-50, <5, nepheline ore >300, 100-300, <100, and alunite > 60, 5-60, <5 million tons. As of 2020, the proven reserves of aluminum by countries: Guinea 7,400 million tons, Australia 5,100 million tons, Vietnam 3,700 million tons, Brazil 2,700 million tons, Jamaica 2,000 million tons, Indonesia 1,200 million tons, China 1,000 million tons, India 660 million tons, Russia 500 million tons, Saudi Arabia 190 million tons, Malaysia 170 million tons, and Kazakhstan 160 million tons.

1.4. Aluminum is a rock-forming lithophilic element with a clark content of 8% in the earth's crust. The amount of aluminum in the rock varies from 0.45% (in ultra-basic rocks) to 10.45% (in clay and shale). The main minerals containing aluminum are shown in Table 1.

Major minerals containing aluminum

Table 1

Mineral	Chemical formula	Oxide content, %
Gibbsite	$Al_2O_3 \cdot 3H_2O$	65.40
Boehmite	$Al_2O_3 \cdot H_2O$	84.97
Diaspore	$Al_2O_3 \cdot H_2O$	84.97
Kaolinite	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	39.5
Corundum	Al_2O_3	100
Nepheline	$(Na_x,K_y)_2O \cdot Al_2O_3 \cdot 2SiO_2$	32.0–35.0
Alunite	$(Na_x, K_y)_2 \cdot Al_2(SO_4)_3 \cdot 4Al(OH)_3$	37.0
Leucite	$K_2O \cdot Al_2O_3 \cdot 4SiO_2$	22.0–24.0
Kyanite	$Al_2O_3 \cdot SiO_2$	63.0
Andalusite	$Al_2O_3 \cdot SiO_2$	63.0
Sillimanite	$Al_2O_3 \cdot SiO_2$	63.0

The main minerals of industrial importance are bauxite ore hydroxides: boehmite (AlOOH), hydrargillite or gibbsite [Al (OH) 3], and diaspore (HAlO2). Depending on the predominance of minerals in bauxite, there are different types of gibbsite, chamosite-boehmite, chamosite-boehmite-gibbsite, gibbsite-boehmite (occasionally diaspore), and boehmite-kaolinite-gibbsite and kaolinite-containing gibbsite.

1.5. Although the main raw material for aluminum production is bauxite, but other types of raw materials (apatite-nepheline, nepheline, alunite ore) are used in aluminum production due to limited resources of high quality bauxite in some countries. During its processing and extracting of aluminum, vanadium and gallium are extracted by byproduct. The main industrial types of aluminum deposit are shown in Table 2.

Bauxite is an ore composing of aluminium hydroxide (gibbsite, boehmite, diaspora) and iron oxide, hydroxide and clay minerals. Content of aluminium oxide is 37-50% in bauxite and silica modulus or ratio of alumina to silica is 2-12 in the ore. If the silica modulus of bauxite is less than 0.85, it is called sialite, and 0.85-2.0 is called allite. Depending on the mineral composition, the bauxite is divided in to 2 main types: monohydrate-$HAlO_2$ (boehmite and diaspora) and trihydrate-Al $[OH]_3$ (gibbsite). On the other hand, boehmite and diaspora bauxite are widely distributed in ancient rocks, while gibbsite bauxite is common in modern tropical climates.

Silicon oxide is the main toxic compound and is present in the form of free quartz in bauxite and clay or minerals such as kaolinite, halluazite, nakrite, dikkite, chlorite (chamozite), and hydro mica. Among the iron minerals, bauxite contains hematite, goethite, hydrohematite, hydrogoethite, lepidocrocite, maghemite and magnetite. These minerals differently occur in bauxite and form collomorph structure in mixture part of free aluminium oxide. Siderite occurs widely in bauxite. Secondary minerals are phosphate, zeolite and alunite while rutile, zircon, epidote, tourmaline, ilmenite, hornfels, and garnet are included as accessory minerals. In addition to the basic chemical elements, bauxite contains dissolved gallium, vanadium, scandium, and uranium.

The type and form of the minerals in the main component affect the choice of bauxite technological processing mode, and the ability of alumina minerals to react in alkaline solutions varies. When classifying aluminum ore types, it is appropriate to classify bauxite not only by mineral type but also by lithological characteristic. It is important to classify bauxite into subdivisions according to their lithological composition (rocky or dense, loosy, clayey, etc.), and in most cases the technological, physical, and mechanical properties of the ore are directly related to them. For example, dense, and fossilized solid bauxite is higher in silicon modulus than clay bauxite.

Industrial type of aluminium deposit and major type of ore

Table 2

Industrial type	Natural type of ore	Mineral type of ore	Average content Al_2O_3, (SiO_2), %	Co-component	Technological type of ore	Example of a deposit
Bauxite-laterite	Lineal and areal laterite weathering of magmatic, sedimentary and metamorphic rocks	Goethite-chamosite-boehmite	49 (8)	Ga	Metallurgical aluminium (pyro-and hydrometallurgical)	Vislovsk, Melihovo-Shebekinsk, Upper-Shugorsk (Russia)
	Areal laterite weathering (cap) of magmatic, sedimentary and metamorphic rocks	Gibbsite	46–54 (1–5)	–	Same as above	Boke, and Fria (Guinea), Trombetas (Brazil), Djarela (India)
Mixed /polygenic/ bauxite	Lens-type formation in terrigenous and carbonate rock and eluvial and cover with transition	Goethite-chamosite-boehmite	46–51 (5–9)	Ga, V	Same as above	Vezhayu-Vorykvinsky (Russia)
	Weathering cover with transition and eluvial developed in terrgenous rock	Gibbsite	53–59 (3–10)		Same as above	Weipa (Australia)
Terrigenous sequence with bauxite sedimentary	Bauxite-bearing terrigenous (lens-shaped and layer-like formation filled-up depression structure of terrigenous rock)	Kaolinite-gibbsite-boehmite	45–53 (15–18)	Ga, V	Metallurgical aluminium (magnetic-flotation-pyro and hydrometallurgical)	Iksinsk, Plesetsk (Russia)
	Bauxite-bearing terrigenous (lens-shaped formation filled-up small and medium depression-structure of carbonate and terrigenous rocks)	Kaolinite-gibbsite	40–43 (4–8)	Ga, V	Same as above	Amangeldin (Kazakstan) Tatarsk, Verkhoturovsk, Central (Russia)
Sedimentary and carbonate sequence of bauxite	Bauxite-bearing terrigenous-carbonate (lens-shaped and layer-like formation filled-up karst valley in carbonate rock)	Boehmite-diaspore and gibbsite	50–54 (2–11)	Ga	Metallurgical aluminium (pyro-and hydrometallurgical)	Kalynsk, Cheremukhovsk (Russia), Manchester, Saint-Elizabeth (Jamaica),

						Khalimba (Hungary), Alag uul (Mongolia)
Nepheline	Alkali gabbro (stock and dykes)	Nepheline	22,5 (18–24)	–	Metallurgical aluminium (magnetic-flotation-pyro and hydrometallurgical)	Kiya-Shaltyr, Goryachegorsk (Russia)
	Central-type intrusion of agpaitic nepheline syenite (layer-like bodies)	Apatite-nepheline	13,6	Apatite, spehen, Ga, Rb, Cs	Same as above	Rasvumchorsk, Kukisvumchorsk, Yuksporsk (Russia), Ujigiin gol (Mongolia)
Alunite	Layer-like and vein bodies in tuff and secondary quartzite	Alunite	20–25	V, H_2SO_4, quartz	Metallurgical aluminium (pyro-and hydrometallurgical)	Fan-Shani, Taikhu (China), Zaglik (Azerbaijan), Bosageinsk (Kazakstan)

1.6. The reason bauxite is considered a complex raw material is that in addition to aluminum, elements such as vanadium and gallium have become economically attractive. In the Bayer method of processing aluminum, these metals are often transferred together in solution, so vanadium and gallium can be separated from the solution with economic efficiency. However, other ore compounds, such as iron, titanium, scandium and chromium, are currently not practical in terms of production.

The bauxite deposit is in the form of a cover, and such deposits have significant reserves, good quality bauxite ore, and favorable conditions for mining and exploitation.

Laterite type of deposits account for the majority of the world's bauxite reserves. Their formation is due to the very deep chemical weathering of aluminosilicate rocks of different compositions and ages in the variable humid tropical climate. Most of the deposits are located on ancient plateaus and large anticline structures in Africa, India and South America. The bauxite deposit is in the form of a cover, and such deposits have significant reserves, good quality bauxite ore, and favorable conditions for mining and exploitation.The surface cover or thickness of upper part of the bauxite deposit reaches 5-10 m in the plateau-like higher hills. In Russia, this type of Vislovsk deposit is of Lower-Carboniferous age, and the main ore-bearing mineral is boehmite.

Deposits of mixed origin are characterized by transitional genesis of terrigenous laterites and sedimentary rock. The main features of these deposits are large and medium-sized lenses of laterite and sedimentary origin bauxite. The largest is the cover-type formation, which is formed by filling the hollows and depressions of various origins, shapes, and morphologies. The main representative of this type of deposit is a bauxite deposit with Neogene age gibbsite in northeastern Australia.

There are two or three horizons in the bauxite sequence, which are porous, nodular, flat-tabular, pizolite-type bauxite, and cemented by loose materials of chemically similar mineral.

The ore quality is good but low comparing to laterite deposits. In Russia, this type of deposit is the late Devonian Vezhayu-Vorykvinsky deposit, and the main ore mineral is boehmite. Sedimentary deposits formed in the terrigenous sequence are distributed in plate structures in Russia, China and North America. Bauxite deposits are usually associated with coal-bearing seams, however, accumulation of bauxite and coal differs in terms of timing and spatial extent.

In the Tikhvin bauxite-bearing region of Russia, there are ravine-valley type deposits, the main features are it forms a small, longitudinal extended lens-like deposition along the narrow linear structure. Bauxite deposits belonging to the stratum type are irregularly surrounded on the surface, the thickness is not constant, and usually consists of boehmite, gibbsite or boehmite - gibbsite. The karst-type deposits characterized by a large number of small-sized bodies that fill small cavities. The location of the deposition is determined by the geological settings of pre-ore carbonate rocks and its shape and size depend on characteristics of the cavity containing it.

The thickness of ore body is usually large (150m) and small-sized ore body contains low reserve and bad quality ore. In addition to bauxite, bauxite-bearing strata contains a large amount of good quality, refractory clay. The internal structure is very complex and bauxite and clay layers are intercalated.

Chemical and lithological composition of bauxite is unstable and the gibbsite predominates in Meso-Cenozoic sediments while bauxite with boehmite composition dominates in Paleozoic sediment. In Russia, this type of deposit is the early Carboniferous Iskinsk and Timshersko-Puzlinskii deposits and the major ore mineral is boehmite. Moreover, the major ore mineral is gibbsite in Cretaceous-Paleogenic deposits of Central, Verkhoturovsk, Sukhovsk and Edinsk.

The Alag uul bauxite deposit can be included in the example of diaspora-bearing deposit. In addition, it was defined that content of Al_2O_3 is 20.03-22.71% in the 5-10 cm thick sedimentary bauxite layers within the coal-bearing formation of Khuren gol.

Sedimentary deposits of carbonate stratum are characteristic of the Hercynian and Alpine folded belts. The forming of the karst surface in pre-mineralization and the accumulation of bauxite usually took place in reef limestone of shallow water troughs. In karst-strata-type deposits, the shape of the ore body is layered and lens-shaped. The roof parts of the ore bodies are usually flat and in some cases wavy, while the bottom parts are uneven.

By its bed size it belongs to large or medium, the size of the deposit ranges from a few hundred meters to kilometers along the strike, and the thickness ranges from 5-7 to 10-12 meters. The bauxite quality is very good and stable and contains monohydrate diaspora, diaspora-boehmite as well as boehmite.

The formation of karst-type deposits is associated with the karst zone and is dominated by a wide range of karst depressions that determine the shape and size of the bauxite deposit. An example of this type of deposit is the Jamaican deposit. Karst-lens type deposits are smaller than karst-layer deposits in size but have better quality bauxite. This type of deposit belongs to the Mediterranean countries. Karst-tube deposits are characterized by the formation of many small deposits, such as nests and tubes. The geological environment, deposition and ore quality are similar to karst-lens deposits. In Russia, such deposits as Kalinsk, Novo-Kalinsk, and Cheremukhovsk are of late Devonian age, and the main ore mineral is the diaspore.

Nepheline ore is the second most important aluminum production, but it is occured only some countries, such as Russia and Mongolia. The value of nepheline rock is determined by its nepheline content. The nepheline compositions are: Al_2O_3 29-35%; SiO_2 43-48%; R_2O 17–20% while Na_2O can be replaced by 10–20% K_2 and CaO, Ga_2O_5, V_2O_5, and Fe_2O_3 are occurred as mixture. Nepheline-containing rocks are alkaline stocks and veins that sometimes form laccoliths, which are associated with ultra-basic, basic, and acidic magmas. Alkaline rocks develop in the orogenic region in addition to the ancient platform and plates.

Examples of such deposits in Khuvsgul district are deposits, occurrences and mineralization of Beltesiin Gol, Dushiin Gol, and Uvur Maraat, which are genetically associated with alkaline gabbro-nepheline syenite of the Early-Mid Devonian Ujig complex and alkaline syenite-nepheline syenite massifs of the Upper Carboniferous Dund khem gol complex. For the Beltes gol, the south body is composed circle-shaped body with zonal structure and an area of 3.8 km^2. 75-150 m wide outer zone is composed of ijolite and middle zone is 100-250 m wide and consisted of ijolite-urtite. While, the central zone consists of 50-100 m small bodies that transition from urtite to nepheline. Its aluminium probable resources were estimated at 222.0 million tons (1985).

Urtite is relatively rich in nepheline (Kiya-Shaltyrsk deposit) and containing 75-85% nepheline and 10-15% pyroxene, and there is no need to concentrate such ore. Alkali gabbro are ijolite and theralite (gabbro), contain up to 50% dark minerals, 30-50% nepheline and feldspar, and nepheline concentrate can be extracted from them. In the Murmansk region of Russia, large reserves of apatite-nepheline ore have been identified, and its processing waste is a high-quality complex raw material of alumina.

Nepheline-containing rocks are complex raw materials and are valued by two parameters:

1. Alkali module (K_2O+N_2O/Al_2O_3 molecular ration),

2. SiO_2/Al_2O_3 molecular ratio.

The ratio of the most efficient processing and enrichment of nepheline ore, that the acid module should be close to one, and the molar ratio of SiO_2 / Al_2O_3 should not exceed 3.3-3.4.

The alunite ore deposit is associated with the formation of a young volcano and is located in the mobile zone of the Earth's crust, in Asia, Australia, the Pacific island arcs of North and South America, and in the tectonic zones of North Africa and Eurasia.

Alunite belongs to a group of aluminium and alkali metal double sulfate and contains 37% Al_2O_3, 38,6% SO_3, and 11,4% alkali. Therefore, alunite ore is used as a complex raw material for aluminium oxide, potassium fertilizers and sulfuric acid. The alunite mineralization forms in varies geological environment, specifically, in zones of volcan and secondary quartzite (quartz-alunite), coal-bearing seam as well as oxidation zone of sulfide deposit.

Because alunite is formed by impact of sulfuric acid-rich sulfur gas and solution to the host rock, so large deposits contain stratified ore bodies formed by vein and metasomatite alteration.

The largest deposits in the world are the Fan-Shan and Taihu deposits in southeastern China, and Zagliksk, Gushsaisk, Begankovsk and Pekinsk in Russia.

However, there are a number of alunite occurrences associated with relatively common epithelial mineralization in Mongolia, but the potential for the use of aluminum-bearing clay minerals and technological studies or aluminum raw materials have not been well studied.

When aluminum-rich sediments affected by metamorphism, aluminum oxides recrystallize and form disten-andalusite-sillimanite schists, which are thought to be suitable for use as aluminum ore.

Experiments are also being carried out to separate aluminum from coal ash (lignite ash contains 10-25% Al_2O_3 or more).

1.7. As the use and demand for aluminum and its alloys increases, the aluminum oxide industry requires new types of raw materials. Experiments to extract aluminium are underway in many countries, for example, high-grade aluminum clays (USA), leucite (Italy) and andalusite (Sweden)-bearing rocks, labradorite (Norway), alunite and aluminum schist (Japan) as well as to extract aluminium by mixing with high-alumina clays with coal ash (Germany). However, the aluminum extracted by these methods costs 4-5 times more than the processing of high quality bauxite. There are deposits of kaolin containing up to 40% of Al_4 [$(OH)_8Si_4O_{10}$] in Russia, but the level of exploitation has not yet been fully studied.

In addition to kaolin and clay deposits with high alumina content, dawsonite [$NaAlCO_3(OH)_2$], which is associated with the accumulation of lake-derived evaporite sediments, is a promising raw material for sodium and aluminum.

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

2.1. Following the Instruction "Classification and guide of Mineral Reserves Mineral Resources of Deposits" that approved by the order No. 203 of the Minister of Mining of Mongolia, dated on September 11th, 2015, and depending on size of ore body, shape and thickness, changes of internal structure and quality of mineral resources of bauxite deposit, the bauxite deposits belong to any one of I, II, and III groups.

Group I. This group includes the deposits containing ore bodies with simple geological settings, large area (0.5 - n10 km2), undamaged or slightly destructed strata, low thickness variation (22 to 10-15 m), and stable quality of bauxite.

Group II. This group includes the deposits containing lens type-strata-like or lens-like and large to medium-sized (area of 0.3-1.5 km^2) ore bodies with complex geological settings, high thickness variation (1.5-32 m ad in average of 4-7 m), and stable quality of bauxite. Also, the deposits with following characteristics can be included in the group: karst-strata-like formation with large area (0.5-1.2 km2), flat roof parts, uneven bottom part, and thickness variation (1-30 m and in average of 4-6 m) and unstable bauxite quality. In addition, large and medium-sized, symmetrical stock-type bodies and parametically stable nepheline deposits are also included in this group.

Group III. This group includes the bauxite deposits with very complex geological settings, medium and small-sized ore bodies (area of 0.2-1 km^2), lens-like and porous formation and sharp change (0.5 to 8-10 m) in thickness.

2.2. It is necessary to explore compexity of the geologic settings of the ore body which hosts more than 70% of total reserves and decide which group the target deposit should be referred to.

2.3. It is necessary to examine the variation of the ore quality and quantity to refer the target deposit to one of the above-mentioned four categories (Table 3).

2.4. The classification of a deposit and its part is determined by the degree of complexity of the geological formation of the main ore body, which contains at least 70% of the total reserves of the deposit.

2.5. The exploration system and grids density selection depends on a number of natural factors such as existing condition of target ore body, its structure, geologic settings, stability, volume and size and variability of economic components. Therefore, it is recommended to use following parameters to categorize the deposits on the regular basis of complexity of the geologic settings.

Ore mineralization coefficient, applied for separation of the unit block certain deposit rserve with interrupted mineralization, is calculated as follows:

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

l_i – linear dimensions of ore intervals revealed by drilling and excavation,

L – total linear dimensions of mineralized intervals resulted from drilling and excavation

1. The complexity coeeficient of the deposit is computed as follows:

$q = \dfrac{N_x}{N_x + N_{xz}}$ where

N_x – number of excavation and drillholes revealing mineralization,

N_{xz} – x number of excavation and drillholes revealing no mineralization.

2. Variability of ore body thickness is calculated as follows:

$V_m = \dfrac{\sigma_m}{\overline{m}}$: where,

V_m – x varioability coefficient of ore body thickness,

σ_m – dispersion of ore body thickness , $\overline{m}$ – average thickness of ore body

3. Grade variability of mineral components is calculated as follows:

$V_a = \dfrac{\sigma_a}{\overline{a}}$: where,

V_a – variability coefficient of grades of mineral components,

σ_a – dispersion of mineral components,

$\overline{a}$ – average thickness of ore bodies.

The table provides the reference of classified groups in relation to some statistical assessments of geologic settings complexity and indicates which group a deposit should belong to.

2.6. The decision to classify a deposit into a particular group takes into account the completeness of all geological information, which shows the maximum change in the shape of the ore body and the content of the ore body.

Statistic assessment and Complexity group for geological settings of deposit

Table 3.

Groups	Complexity parameters of deposits due to geologic settings			
	K_x	q	V_m	V_a
I group deposit	>0.7	>0.8	<40	<40
II group deposit	0.7-0.9	0.6-0.8	40-100	40-100
III group deposit	0.4-0.7	0.4-0.06	100-150	100-150
IV group deposit	<0.4	<0.4	>150	>150

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

3.1. For the explored deposits, it is necessary to have a topographic map, the scale of which would correspond to its size, the peculiarities of the geologic settings and local landscape-geomorphological conditions. Usually 1:2000 and 1:10000 scale topographic maps are drawn up for an aluminium deposit. All exploration and operational workings' excavations (trenches, dug holes, tunnels and underground mines), boreholes, profiles and stations of detailed geophysical observations, as well as natural outcrops of ore bodies and ore-zones should be instrumentally tied. Subsurface mining works and drillholes must be plotted on the plan maps as indicated by engineering survey work (markscheider work). Surveying plans of mining horizons are usually drawn at scale 1:200 to 1:1000, consolidated (unified) plans – at scale not smaller than 1:2000. For boreholes, the coordinates of the points of intersection of the roof and the bottom of the ore body should be calculated and their locations have to be plotted on plans and plane of sections.

3.2. Geologic maps, geologic sections and plan maps are created on the scale of 1:2000 and 1:10000 depending on the size and complexity of deposits and geologic sections, plans, projection planes and if necessary, block diagram and 3D-models should be produced to study the geologic settings. Geological and geophysical surveys determine the ore body volume, shape, ore-forming conditions, structure, extension, characteristics, mineralization, distribution of minerals, host rock characteristics, fold structure, tectonic faults and their relations to the ore body to justify the final estimation of reserves. Apparently, it is necessary to justify the geological boundaries of the deposit and prospecting criteria that determine the location of prospective area within assessed resources in P1-category are estimated.

3.3. Ore body located near the surface, outcrops exposed at the surface and mineralization zones should be investigated by appropriate methods such as prospecting traverses, geochemical and geophysical surveys in addition to mining excavation (trench, channel) and shallow-depth boreholes. As a result of sampling and testing, the shape of ore body, extension, volume, conditions, depth distribution, weathering degree, geological characteristics of roof and bottom parts of bauxite formation, mineral composition, technological properties of ore, presence of karst, tectonic faults and their features are determined in detail; afterwards, detailed determination of mineral composition and technological properties of primary, mixed and oxidized ores allow completing reserve estimation separately for industrial (technological) types.

3.4. In the case of aluminum deposits, in-depth exploration is usually carried out by the borehole method, as well as by a combination of borehole and surface geophysical methods. In the case of shallow ore deposits, exploration will be carried out through boreholes and surface excavations. The instructions for the diamond drilling and the drilling technology regime are to obtain the maximum possible decontamination core of the drilling fluid and host rock for bauxite. During the exploration of deposits with steeply dipping nepheline, alunite strata, and lens-type formation bearing ore bodies, cross-section should be determined for fully revealing the depth, slope angle, and distance between boreholes. In terms of exploration methods, the size and type of geophysical surveys, their correlation with drilling and mining operations, the density of the exploration grid, and the sampling methodology should be consistent with the group of geological formations of the deposit and allow for resource estimation. It is determined based on the geological characteristics of the ore body, considering the capabilities of mining, drilling and geophysical exploration tools, and the exploration and experience of similar deposits.

3.5. From drillholes must be obtained the core in maximum recovery and complete volume and core is well preserved in length; the core can allow determination of placement, thickness and internal structure of ore bodies and host rocks, and alteration nature in vicinity of ore-body, and nature type of ores and their texture and structure well satisfying representativeness of samples. The core recovery at each run of drilling procedure should not be lower than 90%. The accuracy of the determination of the linear core recovery shall be systematically monitored by weight or volumetric method. During bauxite exploration, drilling in the ore zone should take a shortened run and use a drilling slam without contaminating the core. In case of exploration in the ore bodies with loose or weakened sediments, a special drilling technology has to be used to increase the material recovery. The core recovery content and the thickness of the ore interval, which determine the quality of the ore, should confirm the information on the uneven distribution of loose ore and non-conditional beds. For this reason, it requires comparing the sampling results with different core recovery at regular intervals for the main ore types, verifying the information obtained through controlled excavations and geophysical surveys, and using other methods if the core recovery is low or poor.

Geophysical logging should be conducted based on the identified tasks, the geology of the deposit, the geophysical conditions, and the modern capabilities of the geophysical method in order to obtain accurate information by drilling and increase the reliability of the information. The logging studies should be conducted in all drill holes as it is important to determine the ore intervals and their parameters.

Angle azimuth and zenith of wells is measured at each 20, 25, and 50m of interval of underground holes, vertical drillhole with the depth of more than 100m, and all types of adits. The measurement result is plotted in geological sections, plane maps and ore thickness calculation. If the diamond drillholes are intersected with subsurface excavation, the crossed point is examined by engineering survey line (markscheider). The angle between drillhole and mineralization interval must be no less than 30^0. The inclination is given artificially to intersect the ore body with a steep dipping. Also, for ore effective result of exploration it is possible to drill multiple workface boreholes and fan-like holes. The drilling of ore body must be of the same diameter.

3.6. In the case of shallow deposits, the excavation will be carried out in certain areas for the purpose of drilling inspection, geophysical research, selection of sampling technology, determination of moisture content, study of deposition conditions, morphology, internal structure, mineral composition, distribution characteristics and ore type.

3.7. The survey grids and spacing between the holes should be chosen for structural morphological characteristics, type, size, sequence and geological settings of the ore bodies. Table 4 shows the survey grids and spacing used in exploration in the Commonwealth of Independent States. Table 5 shows the survey grids and spacing used in Mongolia's aluminum deposits and the table is used as an example of a nepheline-syenite ore deposit, it is not necessary to use the survey grids and spacing as a reference when planning a geological exploration work. Thus, compared characteristics of the detailed survey-needed area and analysis on available results of previously studied deposits will be basis for proper choice for exploration grids and density.

The survey grids and spacing used in exploration in the Commonwealth of Independent States

Table 4

Group	Structure-morphological type of ore body	Spacing between excavated points intersected the ore body (m)					
		Proved (A)		Measured (B)		Indicated (C)	
		Along striking	Along dipping	Along striking	Along dipping	Along striking	Along dipping
I	Large-sized strata-like deposition with a stable bauxite quality and thickness:						
	• Symmetrical in shape	100	100	200	200	400	400
	• Extended along the strike	100	100–50	200	100	400	200
II	Lens-like and strata-like deposition with unstable thickness and slight changes of bauxite quality:						
	• Large-sized and extended along the strike	–	–	150–75**	100–50**	300	100
	• Symmetrical ore body with large and medium-sized	–	–	100	50	200	200
	Karst-strata like deposition with a complex geological settings, flat roof and uneven bottom						
	• Massive sequence with changes	–	–	100	100	200	200
	• Sequence with abrupt changes and there are some parts without ore	–	–	100***	100***	200***	200***
				With central borehole			
	Medium-sized, karst-hollow like deposition, with complex geological settings, thickness changes and unstable bauxite quality.	–	–	50–100	50–100	100–200	50–100
III	Lens-like sequence with a very complex geological settings, and abrupt changes in thickness and bauxite quality						
	• Medium-sized	–	–			100–50	100–50
	• Small and very small	–	–			25–50	25–50

* The density of the exploration grid for alunite and nepheline deposits cannot be limited to this given value. In some alunite deposits, the density of the exploration grid is 100x100 m for Proved (A), 200x200 m for Measured (B) and 400x400 m for Indicated (C), while for nepheline ore deposits, the density of the exploration grid is 200x200 m for Proved (A) and 200x400 m for Measured (B), and 400x400 m for the Indicated (C) category.

** In the part of grid densification

*** When estimating resources by exploration, the error reduction factor / coefficient is used by comparing exploitation and exploration data.Clarification: Depending on the complexity of geological settings of the deposit, the density of the exploration grid in the evaluated deposit will be 2-4 times denser than the Indicated category (C) for the probable resource (P) and will not necessarily be confirmed by boreholes.

3.8. Detailed exploration will be conducted to confirm the reserves of other parts of the deposit. In the pre-feasibility study during the exploration period, the size and number of the detailed parts should be determined by the licensee and should be denser than the grid density used in other sections. The reserves in the deposits which refer to the group 1 are estimated by Proved (A) and Measured (B) or A+B categories, the reserves in the deposit referring to the group 2 are estimated by Measured (B). On the other hand, it recommends to use two times denser grids compared to C category grids for the deposits which belong to the group 3.

In the detailed study part, the location conditions of the ore body (bed), the shape and quality of the reserve estimated ore body are different from the others. The geological settings, ore quality, and mining-geological conditions may differ within from the range of the reserve estimated area, and in some cases for the entire deposit.

The data obtained from the areas that are under detailed study, will be used to represent the deposit as a whole, such as the complexity of the deposit, the density of the exploration grid related to its geological settings, the reliability of the sampling results, and the calculation parameters. Exploration in mining stages and extraction results are also adoptable for the same purpose as mentioned above.

In reserve estimation on areas that subjected to survey in detail, the exploration grid has to ensure the density is sufficient to substantiate the optimal interpolation using geostatistical modeling methods like as inverse distance weighting, Kriging and others.

Density of exploration grid used in aluminium deposits of Mongolia

Table 5

Group	Name of deposit	Explored year	Shape and size of ore body	Excavation type	The distance between the points where the ore body is intersected (m)		Comment
					Measured (B)	Indicated (C)	
I	Doshiin gol	1969, 1985, 2012-2013	The “North” body was identified in the Doshiin gol massif, which has a surface area of 0.84 km^2 and oval shaped and consisted of ijolite and urtite. The massif was revealed in marbleized limestone of Bayanzurkh formation. The massif has a gabbro-teralite-ijolite-urtite zonal structure from east to west, with Al2O3 reaching 8-11% (alkaline gabbro) and 31% (urtite).	Dug hole, Drilling (up to 509.4m depth): 12436.8 length/m	100x200	200-400	Al_2O_3 (19.42%) reserves in the 200-578 m deep borehole are 28.6 Mt in the “North” or I body by measured (B) and 16.2 Mt in the indicated (C).
			The “Southern” body was found at 900 m south of the “Northern” body. The body has 0.8x2.5 km area and oval-shaped, hosted in marbleized limestone of Bayanzurkh formation, consists of ijolite and urtite and skarnized. The total deposit was estimated to be 59.3 million tons of Al2O3 ore at the time (1985).		100x200	200-400	Al_2O_3 (19.42%) reserves in the 192.0-416.4 m deep borehole are 4.2 Mt in the “Southern” or II body in measured (B) and 3.5 Mt in indicated (C) category.
I	Uvur maraat	1969, 1985, 2012-2013	Zonal structured, late phase foyaite and juvite of Lower Devonian Ujigiin gol complex that intrudes the limestone of lower member of Bayanzurkh formation. A 5.5 km long and 0.3-0.4 km wide gradual transitional strip was found along their boundaries. Nephelinite is in an area of 1.5-2.0 km with idiomorph crystals and porphyritic structure. At that time, it was estimated at 545.9 million tons.	Drilling: 874 length/m	-	200x400 (600x500)	Al_2O_3 reaches to 26.7% in juvite, 20.8% in foyaite and 23.32% in porphyritic juvite of juvite-foyaite contact. 73.9 Mt in Indicated (C) catgory and resources (P) of 47.7 Mt.
II	Alag uul	1978, 2010-2012	It has a complex geological structure, has been fractured, destructed and altered, and is divided into two ore bodies, “North” and “South”, which are 80 km long and 800 km wide. Diaspore bauxite layers extending northeast within ultramafic rocks are 1-22 m thick in the borehole.	Drilling: 1008.8 length/m, 15 bore holes	100x50-100	200x100	4.5 Mt of reserve at an average content of 33.3% Al_2O_3: 798 thousand t oxide (33.3%) in 2.39 Mt of ore of Measured (B) category and 3.2 Mt oxide (33.8%) in 9.6 Mt ore of Indicated (C)

3.9. Each drillhole and excavation result must be documented. It is recommended to take photos if the ore body is characterized by different colors. The roof, walls, sampling workface, and dip and strike extension must be documented; specially appointed commission has to monitor completeness and quality of primary geological documentation, which meets compliance with deposit's geological features, correctness of determination of the spatial position of the structural elements, the preparation of sketches and their descriptions in the prescribed manner. Furthermore, it should be controlled and assessed quality of geological and geophysical sampling (consistency of cross-section and weight of samples, their position corresponding to the peculiarities of the geological structure of the deposit, the completeness and continuity of sampling, the presence and results of control testing), the representativeness of mineralogical and engineering-hydrogeological studies, the determination of volume weight, sample processing and quality of analytical work.

3.10. It is crucial to take samples from each interval identified both in the natural outcrops and resulted from exploration to study the mineral quality, reveal the contact or boundary of the ore body as well as estimate its reserves. The sampling result must be reported in geological description and included in primary documentation.

3.11. The proper choice of geological and geophysical sampling methods is based on geological characteristics and geophysical properties of both host hocks and target minerals during the initial stage of geological survey and evaluation. The selected method or technique must be the most effective, economically efficient and guaranteed for expecting result.

In case of using a number of sampling methods, derived results and accuracy should be compared and assured. It is necessary to follow relevant standard and methodology on sampling method selection (core drilling, trenching, and stripping) to determine the processing quality and evaluate the assurance for the sampling method.

3.12. Exploration sampling is performed under follow up conditions:

- Sampling grids should be consistent; the grid density must be suitable for geologic settings of the target deposit. The grids selection is usually based on exploration practices of similar deposits; for new objects, a pilot test is required. Take samples in the direction in which the mineralization changes the most,

- Sampling procedures should be carried out continuously, at full thickness of the ore body and in as possible as equal intervals with an output in the host rocks by an amount exceeding the thickness of the ore body and entering into layers of gangue rock or substandard contents of ore. For the ore body whose geological boundary or contact is undefined, the sampling must be conducted throughout all boreholes and trenches; for those whose geological boundary is identified, the sampling process should be done within the section scale of the ore body. The samples must be taken from trenches, shaft and channels as well as eroded or weathered areas.

- Sampling is performed separately for each ore types (rock, loose, clayey, other bauxite, urtite, teralite, and nepheline-syenite). The length intervals of sampling are defined by depending on the internal structure of ore body, changes in mineral composition, and other physical-mechanical properties. Thus, sampling with various core recoveries is performed at each interval. Sampling techniques from dillhole (core and mud) are dependable on the type of selected drilling method and quality. In any case, the bauxite sample, host rock and clayey parts should not be contaminated with drilling mud (mud solution).

3.13. Regular control and evaluation in accuracy and relability is required in quality of each sampling method and techniques used for main ore types. The interrelation between theoretically defined and present weights is monitored on the basis of the sample characteristics compared with the elements of geologic settings, preciseness of identified contact or boundary of ore body, theoretically expected size and real size of the taken ore, core sample diameter, and total recovery (the range can be no more than ±10-20% depending on ore density).

Trench sampling accuracy is controlled by sampling from a trench which lies adjacent to the target trench and is with the same diameter; ore sampling accuracy is controlled by taking duplicate core samples from the rest half of the borehole. Precision of geophysical acquisition completed in the natural outcrops is examined by instrument stability and results of normal and controlling measurement conducted under the same condition. The accuracy of geophysical data acquisition is provided by comparing geological and geophysical data resulted from interval sampling with good recovery (90% or more) of core which is not weathered. If an error detected, logging and sampling repeated. To do this, technological samples, bulk samples and mining results can be used. The amount of samples for controlling purpose must be sufficient for making statistical analysis to reveal random or regular error, and determining correction quotient if necessary.

3.14. Sample processing should follow the circuit scheme adopted by analogy with similar deposits. Both main and duplicate samples are processed in accordance to the same scheme. Processing quality, procedure implementation and reasonable condition for using ration “K” must be regularly controlled. Control processing of large-volume samples is made according to specially designed program. The chemical composition of ores should be studied with completeness, providing a reliable assessment of their quality, the identification of harmful impurities and useful associated components. The content in the ore is determined by chemical, magnetic, nuclear-physical, other geophysical, spectral and other methods of analysis established by state standards.

If this type of recommendation is not developed, a similar recommendation developed in other countries (for example, developed by the Russian Ministry of Natural Resources) can be used for this purpose.

3.15. The following compounds should be determined in the bauxite: Al_2O_3, SiO_2, Fe_2O_3, TiO_2, CaO, MgO, FeO, MnO, S, CO_2, Na_2O, and K_2O, C (organic), P_2O_5, Ga, V_2O_5, Sc, and Cr_2O_3. At all stages of the exploration work, Al_2O_3, SiO_2, and Fe_2O_3 are determined in all normal samples, and the content of other elements is determined in bulk samples. Al_2O_3, SiO_2, Fe_2O_3, FeO (in chamosite bearing ore), TiO_2, CaO, S, CO_2, Ga, V_2O_5, P_2O_5 should be determined for the reserve estimation of bauxite deposit and subdivision reserves as blocks.

The following compounds should be defined in the nepheline ore: Al_2O_3, SiO_2, Fe_2O_3, CaO, MgO, MnO, Na_2O, K_2O, TiO_2, P_2O_5, S, CO_2, Cl, Ga, Rb, Cs, Sc, and V2O5. At all stages of the exploration work, Al_2O_3, SiO_2, Fe_2O_3, CaO, MgO, MnO, Na_2O, and K_2O are determined in all normal samples and the content of other elements is determined in bulk samples. The above components must be identified when calculating nepheline ore reserves in terms of the deposit, its parts and reserve sections.

The following compounds should be defined in the alunite ore: Al_2O_3 (total), Al_2O_3 (non alunite), K_2O, Na_2O, SO_3, Fe_2O_3, SiO_2, TiO_2, BaO, P_2O_5, V_2O_5, Ga, and FeO. At all stages of the exploration work, Al_2O_3 (total), SiO_2, Al_2O_3 (non alunite), K_2O, Na_2O, SO_3, and Fe_2O_3 are determined in all normal samples.

Prior to grouping or categorizing samples, the size, main and secondary components, toxic and other impurities, and principal distribution of mineral grades along the strike and dip extension of the ore body have to be identified so that the ore body and its types will be studied well.

Silicon oxide is the main toxic compound and is found in bauxite and clays such as kaolinite, halloysite, nacrite, dickite, chlorite (chamosite), and hydromica in the form of free quartz, as described in Chapter 2.

In addition, chrysotile-asbestos occurrence and mineralization occur in ultra-mafc rocks in the spatial extent of diaspore-bearing bauxite deposits, which is directly related to the genesis of the deposit. Asbestos is harmful to human health and needs to be defined.

For the Mongolia, the asbestos mineralization was identified within the hyperbasite massif of Alag uul and relatively rich ore occurrence was revealed in the watershed of Darvi Range or at 5-6 km east of the Alag uul and elevation of 2123.8 m.

3.16. Assay quality must be regularly checked and the derived result is produced according to relevant recommendations. In addition, regular geological inspection over analysis must be conducted during the period of exploration despite lab assay. Controlling analysis must include main and secondary components and toxic impurity.

3.17. To determine random error, samples taken from the remains of the analyzed samples are submitted to the lab where the previous samples were analyzed prior to the next season. Also, external assay check is conducted by a lab certified for external check in order to reveal the regular errors and give assessment. The assay samples remained after taking for the internal check are sent to external lab check. A standard assay which has got the same composition as the target sample assay can be included in the group of samples (each consisting of 25-30 samples) submitted for external check. All assay samples should be able to represent all types and contents of the ore. If too high content is identified, the assay (group of assay) should be sent for domestic check.

3.18. The assay amount for external and domestic lab check must be capable of being represent each classification of content identified during the analysis period (a season, half year and a year). The classification on content should correspond to the requirements for reserve estimation standard. In case of enormous amount of samples analyzed (more than 2000 per year), 5% of total samples should be submitted to external check. On the other hand, in case of few quantities, at least 30 samples from each type of ore should be sent to external lab check.

3.19. Data processing on external and internal check result is completed within a certain period (season, half year or a year) and follows the lab analysis method of the lab. The lab results are evaluated by statistical methods in order to evaluate regular errors in accordance to standard sample assay results. Random errors detected by domestic assay check must not exceed the limit indicated in the table 6. Otherwise, assay results performed by the lab are unaccepted; the assay along with internal assay check is repeated. Consequently, the reason for causing defects in lab results should be revealed and measures are taken to correct it.

3.20. In case of regular errors detected by external check, arbitration control is carried out in a lab that eccredited in international level and certified to such a kind of activities. Duplicates of ordinary and external assay check samples, stored in the lab, (in exceptional cases, the remains of analytical samples) are submitted to arbitration check. 30-40 samples from each group for which systematic discrepancies are revealed are subject to control. If there are standard sample assay results similar to the samples under study, they should also be included in the encrypted form in the batch of samples submitted for arbitration. For each standard sample assay results, 10-15 control tests should be obtained.

When the arbitration analysis confirms the systematic differences, it is necessary to find out their causes and develop measures to eliminate them, as well as to decide whether it is necessary to re-analyze all samples of this class and the period of operation of the main laboratory or to introduce an appropriate correction factor into the results of the main analyses. Without arbitration analysis taken by Laboratory with International Accreditation, the introduction of correction factors is not allowed.

Acceptable limit of random errors corresponding to categorization of ore component grade

Table 6

Compound	Grade in ore component % (Ga and Ge, g/t)*	Acceptable random errors %	Compound	Grade in ore component % (Ga and Ge, g/t)*	Acceptable random errors %
Al_2O_3	>70	13	Na_2O	>25	4.5
	50–70	15		5–25	6.0
	30–50	25		0.5–5	15
	25–30	35		<0.5	30
	15–25	45	K_2O	>5	6.5
SiO_2	20–50	25		1–5	11
	5–20	55		0,5–1	15
	1.5–5	11		<0.5	30
TiO_2	>15	25	п. п. п.	20–30	2
	4–15	60		5–20	4
	1–4	85		1–5	10
	<1	17		<1	25
Fe_2O_3	20–30	25	V_2O_5	>1	8
	10–20	30		0.5–1.0	12
	5–10	60		0.2–0.5	15
	1–5	12		0.1–0.2	20
CaO	1–7	11		0,01–0,1	25
	0.5–1	15		<0.01	30
	0.2–0.5	20	Ga	>50	18
	<0.2	30		10–50	24
MgO	0.5–1	16		<10	30
	0.05–0.5	30	Ge	>50	18
	<0.05	30		10–50	26
S	0.5–1	12		<10	30
	0.3–0.5	15			
	0.1–0.3	17			

* If the components identified in a deposit are different from those in this table, the acceptable limit of relative mean squared error is determined by interpolation method.

3.21. Any errors at the stages of delineation of ore contact due to results of sampling, processing, and checking and determination of parameters should be evaluated.

3.22. The mineral composition of natural and industrial types of ores, their structural-textural and physical properties were studied using mineralogy-petrography, physical, chemical and other analyzes (XRF, ICP-MS, ICP-OES, AAS, etc.).

Lithologically, for other types of bauxite, it is necessary to determine the mineral form of aluminium oxide (gibbsite, boehmite, diaspore, corundum). In this case, distinctiveness of chamosite-bearing bauxite sort should be considered.

In the case of nephelinite ores, the aluminium oxide-containing mineralogical record should be used to determine their number, the relationship between specific groups, and whether they have grown together with other minerals. The distribution of primary and secondary compounds and toxic impurities needs to be studied and balanced in the form of mineral compounds.

3.23. A qualified professional who has mastered the relevant methodology, should determine the ore volume mass and moisture in ore types and non-conditional/non-standard ore beds and the determination should be followed. The volume mass of dense ore is determined in a qualified sample. While, for less dense, cracked and porous ore body, its volume mass is determined in a sample covered with wax. It should be measured as evenly as possible throughout the deposit area and depth, covering all types of rocks. The volume mass is measured by using gamma ray absorption if certain amount of verification work is done. The moisture is also determined in the sample. Along with volume mass and moisture, the selected sample should be tested for mineral composition and mineralization.

3.24. Chemistry, mineral composition, structure, texture and physical properties of the ore can be investigated partially at the types of ore which need extraction and processing. As a result, the trend of industrial application of the ore is recommended and industrial type and sort is preliminarily identified.

Four. Study of ore technological properties

4.1. The technological properties of the ore are studied in mineralogical-technological, laboratory, expanded laboratory and semi-industrial samples under laboratory and semi-industrial conditions. The technological properties of bauxite are also studied in the laboratory. The use of analog methods, confirmed by laboratory studies of lithology, mineralogy and chemical properties of bauxite, is permitted if there is experience on the industrial processing of the ore.

In the Commonwealth of Independent States, bauxite is used as a raw material immediately after crushing without pre-enrichment. For example, alunite ore is not mechanically enriched and is used cleanly after crushing the bulk of the bauxite.

The enrichment method of nepheline ore is used in the production of aluminium oxide, which includes wet magnetic separation and flotation.

The technological properties of nepheline and alunite ores are studied in laboratory and semi-industrial conditions.

4.2. Geology-technological mapping is used to classify ore technology types and varieties, and a sampling grid is selected depending on the number and frequency of ore interlacing in nature. Mineralogical-technological and low-tech samplings are the means to identify each type of the studied ore. As a result of testings on the samples, geological and technological categories of the ore are determined and the industrial type of the ore is identified; meanwhile, geology-technology maps, plan maps and sections are produced. On laboratory and expanded laboratory samples, the technological properties of all selected industrial (technological) types of ores should be studied to the level necessary to select the optimal technological scheme, and ore-processing and determining the main technological indicators of enrichment processes and quality of the expected products.

4.3. Apparently, the semi-industrial pilot test is conducted on the agreement to license holder (user of subsoil) and in accordance to technology method that is included in the project design. Technological samples shall be taken in accordance with relevant procedures and it shall be documented.

4.4. Expanded laboratory and semi-industrial technological samples are able to represent the industrial type of ore including chemical and mineralogical composition, average composition of physical and other characteristics and the potential impurity shall be considered.

4.5. Ore technology testing has been studied to obtain initial information on the complete extraction of industrially significant co-compounds that are sufficient to select the ore processing technology scheme. The industrial and technological types of ore should be identified in accordance with relevant standards.

4.6. Mineral technology method is used to study the grindability of ore by crushing bauxite ore to -50 and -3 (1) mm and nepheline ore to -5 mm. It should be determined the oxidation degree of the ore, the mineral and chemical composition, structure and texture properties, grindability of the ore, the physical and chemical complete properties of the mineral, as well as determine the degree of difference in these properties. The phase separation efficiency of aluminum minerals, depending on the degree of crushing, is determined, and the possibility of flotation, gravitational and magnetic separators is determined by ore sieving and gravitation analysis. Ore processing goes through two main stages: extracting the aluminium oxide by pyro-and hydrometallurgical methods and determining the metallurgical limit for the production of aluminium oxide by electrolysis of molten aluminum fluorine salts. Some types of bauxite (gibbsite, kaolinite-gibbsite) and nepheline ores with high content of toxic impurities must be subjected to pre-magnetic-gravitational enrichment.

4.7. The most important method of processing bauxite into aluminium oxide is the Bayer hydrochemical method. For the general scheme of the process, after grinding, the bauxite is first treated with a solution of sodium hydroxide or, conversely, with an alkaline solution of aluminum. As a result, the alumina in the bauxite is converting into a solution called sodium aluminate or $NaAlO_2$. The Bayer method is simple and inexpensive, consuming four times less energy than the sintering (melting) method, but it can only be used to process low-silica bauxite. To extract alumina from bauxite with a high-silica content, bauxite is mixed with limestone and soda, melted at 1150-1250°C, and then leach with a weakly concentrated circulating alkaline solution. It can be used to use high-silica and high-carbonate bauxites.

Alag uul bauxite was defined as low-silica, high-iron and diaspora bauxite, and by mineralogical analysis, it was determined that in addition to diaspora, spinel $(Fe_{0.5}Mg_{0.5})Al_20_4$ and corundum Al_2O_3 as alumina-containing major minerals. Studies have shown that fine, anhydrous iron oxides form during autoclave leaching (Bayer) by iron hydroxide dehydration.

In the case of hydrohematite (Fe_2O_3, H_2O), this process is irreversible. Dehydrated goethite α-FeOOH and hydrogoethite during autoclave leaching, rehydrates in thickening process, make it difficult to separate the red sludge from aluminium solution. In other words, bauxite contains a lot of iron oxide, while iron oxide has a significant negative impact on the technological process. While, hematite and pyrite less impact on extraction of aluminium oxide from diaspora bauxite. During autoclave leaching, chlorite is completely dissolved in aluminate solution to form sodium hydroaluminosilicate and fine magnetite.

This shows that different iron minerals have different effects on bauxite processing.

In the case of Alag uul bauxite, iron minerals do not have a significant effect on the turning of bauxite alumina to solution.

In some Russian aluminum smelters, by adding calcined soda to the technological regime and using in combination of Bayer and smelting methods to process the bauxite of different qualities at the same time.

Nepheline raw materials (ore or concentrate) are burned with limestone at 1250–1300°C and adding the weak solution of dicalcium silicate to separate the silica. The resulting cake is leached with a circulating soda-alkaline-aluminate solution, into which sodium and potassium aluminates pass, and dicalcium silicate remains in the sediment.

After desiliconization, the aluminate solution is carbonized with carbon dioxide gas to decompose sodium and potassium aluminates. The aluminum oxide hydrate will precipitate during carbonatization. Filtered and calcined alumina hydrate is a commercial product. Soda and potash (K_2CO_3) are obtained from the filtrate. White sludge is used for the production of Portland cement.

In the production of 1 ton of aluminium oxide, 1 ton of soda and potash products and 10 ton of cement are extracted as by-products. Thus, all components of the nepheline raw materials are fully used. The yield of alumina products is 80-83%, and products containing soda are about 80%.

After grinding the alunite ore, it is roasted / incinerated in a “liquid-based” furnace, then the reduced alunite is dissolved in a constantly circulating alkali (130 g/l Na_2O) at 80°C and the red sludge is transferred to the tailings.

After desiliconization, clarification and evaporation of the aluminate solution, alumina hydrate is separated, washed, and calcined.

The evaporated sulfate salts are converted to potassium sulfate, and the sulfur dioxide from the "liquid-based" incinerator is converted to sulfuric acid.

Prospective methods of aluminum ore processing include radiometric separation of large crushed ore lumps; bulk sorting of iron and silicon content in accordance with ore standard requirements; and magnetic separation of small (-10 mm) materials using a rotary separator with a high-intensity magnetic field.

4.8. Aluminum oxide is a commercial product of aluminum ore processing and concentrating. Its basic quality requirements are determined by the content of the main useful component (Al_2O_3) and the toxic impurities (the total content of SiO_2, Fe_2O_3, Na_2O + K_2O converted to Na_2O).

The quality of bauxite is regulated by an agreement between the supplier (mine) and the metallurgical enterprise or must comply with existing standards and specifications, which must indicate: technical requirements for ores, considering the processing method; acceptance rules; ore testing methods; conditions of transportation and storage, as well as supplier's guarantees.

Requirements for the bauxite content, physical and chemical parameters of bauxite, and aluminum quality used in the Commonwealth of Independent States, are shown in Table 7-9 as a reference.

Bauxite ore mark and type of uses

Table 7

Mark	Main direction of uses
EB-1/ЭБ-1	Production of electrocorundum 18A
EB-2/ЭБ-2	Production of electrocorundum 14A and 15A
TSB-1/ЦБ-1	Production of alumina cement
TSB-2/ЦБ-2	Cement production
OB/ОБ	Production of refractory materials
GB/ГБ	Production of aluminium oxide
MB/МБ	Steel processing in open-hearth furnaces

Physical and chemical parameters of bauxite

Table 8

Parameter	Ore mark requirements						
	EB-1/ ЭБ-1	EB-2/ ЭБ-2	TSB-1/ ЦБ-1	TSB-2/ ЦБ-2	OB/ ОБ	GB/ ГБ	MB/ МБ
Complex parameter of quality “B”, not less	41	31	31	0	6	6	0
Percentage of alumina (Al_2O_3),%, not less	–	43	34	28	–	28	28
Other compounds,%, not more S	0.3	0.3	0.8	–	0.5	–	0.2
P_2O_5	0.5	0.5	–	–	–	–	0.6
CaO	0.1	0.25	2.0	–	1.5	–	–
Fe_2O_3	–	–	–	–	3.0	–	–

Notation. Complex parameter of quality “B” is an expression of the following type: Al_2O_3 - a1SiO_2 –a2Fe_2O_3 - a3CO_2 - a4S + a5CaO + a6 p.p. - a7; The values of the numerical coefficients a1 ... a7 are determined by specific feasibility studies for each deposit.

Requirements for the quality of aluminium oxide
(The first indicator is higher sort; the second is the lower sort)

Table 9

Production	Al_2O_3 content,%, not less	Mixture content, %, not more			Weight loss during liming, %, not less
		SiO_2	Fe_2O_3	For Na_2O $Na_2O + K_2O$	
Primary aluminum and special mark ceramics produced by electrolyte	30–25	0,02–0,05	0,03–0,05	0,4–0,5	0,08–1,0
Primary aluminum produced by electrolyte	30–25	0,08–0,2	0,03–0,05	0,5–0,6	0,9–1,1
White electrocorundum	70	0,08	0,2	0,3	0,4
Special type of ceramics	95–93	0,1	0,4	0,1–0,2	0,2
Electrical insulation products and special types of ceramics	93	0,15	0,6	0,3	0,2
Cast iron catalysts	25 (not more)	0,05	0,4	0,4	1,5

4.9. In Russia, nepheline concentrate and urtite are successfully processed at the Pikalev and Achinsky aluminum smelters, but the technical specifications for nepheline ore, the main raw material for the production of alumina, are not very transparent.

4.10. According to the Khuvsgul nepheline syenite ore technology study, the alkali modulus is 0.45, the silicon modulus is 1.73, the ijolite-urtite Al2O3 is 24.9%, and the quality of the ore is classified as first grade according to the classification used in Russia (1975). The following Table 10 compares the main parameters of the Dushiin gol and Uvurmaraat deposits.

Some ore quality parameters of Dushiin gol and Uvurmaraat nepheline

Table 10

Name of deposit	Average content, weight %			
	Al_2O_3	SiO_2/Al_2O_3	Fe_2O_3	K_2O+Na_2O/Al_2O_3
	19.42	2.2	6.3	0.55
	25.56	1.97	0.87	0.55
Industrial requirements for ijolite-urtite	Not less than 21.0-24.0	Not more than 3.3-3.4	5-7	Lesser than 1

4.11. For co-components, in accordance with the "Methodical recommendations for a comprehensive study of deposits and the calculation of reserves of associated minerals and components", approved by the Ministry of Natural Resources of Russia, it is necessary to define the intermediate products (aluminate solutions) and content in alumina production wastes, and also condition of deposition, the possibility and economic profit of their extraction.

4.12. When processing of all types of aluminum ore, it is required to study the water supply cycle, the specific consumption of fresh water added to the circulation during certain operations, the treatment of industrial wastewater, and the disposal of alumina production wastes.

4.13. Basic requirements and calculation principles for the level of processing of mineral ores, concentrates and final products in determining the royalty for all types of products extracted, sold, shipped for sale, or used by the mining license holder approved by the Government Resolution No. 193 of 2011 follow the identification methodology. The document states that the requirements for aluminum ore are that the aluminum ore-bauxite consists of aluminum oxide, alumina hydrate, iron oxide and silica, and that the alumina content in bauxite is 40-60% or more and in concentrate >45%. The nephelinite and alunite have not been mentioned here.

Five. Studies of hydrogeological, engineering-geological, geo-ecological and other natural conditions of deposit

5.1. Hydrogeology studies focus on hydrogeological conditions including water-bearing layers, aquifers and saturated zones within the target mining area and solutions to potential problems related to de-watering and water consumption issues. The study on the hydrogeological condition of the deposit will be followed the "Thematic, medium and large scale hydrogeological mapping, guidelines and requirements for hydrogeological survey of deposits during mineral exploration" which is approved by the Order No. A/237 of the Minister of Mining and Heavy Industry dated December 12, 2017. The study of water-bearing layer is top priority in the study of the hydrogeological conditions of the deposit. It is required to determine the main indicators by each water-bearing layer of hydrogeology, which include lithology, distribution, thickness, collector type, recharge condition, interdependence between aquifer and ground water, watertable in borehole and excavation, discharge, water volume entering the mine and other parameters. In addition, it should be determined the chemical composition and bacteriological conditions of the mine water, the impact on the mine's concrete, steel and polymer structures, and the content of beneficial and toxic impurities in the mine water. The followings should also be studied and evaluated:

- To determine the chemical composition and bacteriological conditions of the ground water of a deposit, corrosivity impact on the mine's concrete, metals and polymer structures, and the content of beneficial and toxic impurities in the water as well as for the deposits being mined the chemical composition of mine water and wastewater;
- To assess the possibility of using drainage waters for water supply or extracting valuable components from them, as well as the possible impact of their drainage on the underground water intakes operating in the area of the field;
- To advise on the need for further detailed research and assess the environmental impact of the mine;
- To evaluate water resource for future consumption purposes such as mining, processing plant, drinking and technical water supplies
- In a case of planning to use the drained water from the mine, the estimation of exploitable resource will be guided by appropriate normative and methodological documents.

Within the framework of the assessment of the industrial significance of solid mineral deposits, the issues of domestic water supply of the mining industry will be solved at the level of its potential, explored and used resources.

Based on the results of the hydrogeological survey, recommendations will be made on the development of a mining project on the following issues: draining of geological massive, use of drained water, water supply sources and environmental protection.

5.2. Conducting engineering-geological and geotechnical surveys at the deposits during exploration is necessary to provide information support for the development project and to calculate the main parameters of the open pit, underground workings and pillars, standard certificates for drilling and blasting operations and fastening and to improve the safety of mining operations.

Engineering geology and engineering-geotechnical requirements for future underground and surface facilities are regulated by the norms and rules of the "General Basis for Engineering Survey of Building and Facility" /BNbD 11-07-19/ approved by the Minister of Construction and Urban Development Order No. 138 of 2019.

The following set of parameters is understood as engineering geological conditions: landscape and geological settings (soil composition, condition, conditions of their location, characteristics) that affect the planning, construction and operation of cities and buildings within the territory, area and strip, hydrogeological conditions, geological and engineering-geological.

In results of the research on the engineering-geological condition of the deposit, it has to solve following items:

- To study physical and mechanical properties of the target ore and its host rocks especially when saturated to water,
- To study engineering-geology and geotechnical features of rock massif and units for the deposit,
- To study geotechnical feature, their anisotrophy, rock composition, cracks, faulting texture, condition to karsting, erosion in weathering zone, and recent geological process that are considered as the major trouble-causing factors to mining operations.

In addition, the following geotechnical issues should be considered: tectonic faulting, fractured zones and rocks, grindability and level of ore, fillers of faults, chance to water leaking along the strike and dip of fault, and structure of massif.

Also, it is required to identify temperature mode of frozen units in some regions; to determine upper and lower boundary of the frost layers; melting point, depth distribution, and physical properties of rock units at the melting temperature and seasonal freezing and melting depth.

During the engineering geological survey the toughness of rock units at the quarry roofs and walls is assessed and derived result is applied to the calculation of subsurface mining parameters.

If there are underground and open pit mines operating in the same type of hydrogeological, engineering-geological and geotechnical conditions in the deposit area, information on the underground and open pit irrigation and engineering-geological and geotechnical conditions should be used to determine these characteristics.

5.3. In deposits where natural gas (methane, hydrogen sulfide, etc.) has been identified, the composition and content of the gas should be studied to determine the pattern of changes in the deposit area and to depth.

5.4. Potential adverse effects on humal health such as toxic gas, high radiactivation and geothermal conditions should be determined.

5.5. The area which is excluded the exploitation target zone although lying within the same district should be designed for civil engineering purpose such as building apartments for employees, plant constructions or stockpile designated area. Information will be provided on the availability of construction materials for local use, and on the potential for the use of the deposit cover and bedrock as construction materials.

5.6. The ecological studies cover following issues:

- To determine basic parameters of natural environment: degree of radiation, quality of air, ground and underground water, characteristics of topsoil, flora and fauna etc.,
- To predict potential impacts of the proposed construction on surrounding environment: emission of dust into the neighbouring area, ground and underground water contamination, soil contamination with waste water from the mining plant, air pollution etc.,
- To evaluate natural resources allowed for mining operation: woods, water resource for technical application, locating areas of main and subsidiary plant facilities, soil, host rock and uneconomical commodity dump etc.,
- To assess potential hazards such as the nature of the impact
- To evaluate dynamics of pollution source and the boundaries of their impact zones.

It has to be determined topsoil thickness, conduct agrochemical analysis on loose sediments, assess potential adverse impacts on soil and rock units as well as possibility of the extracted areas to be recovered with vegetation cover; all these measures are significantly important to carry out rehabilitation after mine closure.

5.7. In the case of deposits of other types of minerals forming individual bodies within the host and cover sediments, they should be studied to determine their industrial significance and potential applications.

5.8. Engineering-geotechnical exploration will be included in the engineering-geological survey and will be implemented within the framework of the General Basic Norms and Rules for Construction Engineering Research approved by the Order No.138 of the Minister of Construction and Urban Development in 2019.

Six. Reserve estimation and resource evaluation

6.1. Reserve estimation and resource assessment on aluminium ore deposit is completed in accordance to the requirements of the “Classification and guideline of mineral resources and reserves of deposits” approved by order No. 203 of the Minister of Mining and Heavy Industry of September 11th, 2015.

6.2. The reserves are calculated by blocks and it is characterized by following items:

- the same degree of exploration parameters and study level determining the quantity and quality of mineral resources;
- homogeneity of the geological structure or approximately the same or similar degree of variability in the thickness, internal structure of the ore bodies, the ore composition, the main indicators of the quality and technological properties of the ore;
- stability of ore-body positions, the reserve blocks of the ore bodies located in the same structural element (on the same limb or in core of fold, or in same tectonic block, limited by faults); and
- Common mining and technology conditions of operation.

The reserve blocks for steeply dipping ore bodies, are separated along the striking: according to the order in which the resource is planned to be used by exploration grid, and along the dipping: by horizon of the excavations or boreholes.

If it is not possible to determine the shape (geometry) and boundaries of the spatial distribution of ore bodies and types of ore technology, the quality and quantity of ore resources in the reserve blocks shall be determined by geostatistical methods.

6.3. The following additional conditions should be considered in the resource estimates that reflect the characteristics of the aluminum ore deposits:

Proved reserves (A): The Proved (A) class reserve is calculated in the first group of deposit subjected to its detailed study area. Boundaries of reserve blocks shall be restricted to only excavation workings and exploration boreholes.

In addition, it is considered as Proved (A) class, if the part of the deposit locating under operation has been getting prepared or ready for mining excavation in results of completing exploration and mining excavation works. The Proved (A) class reserves are stated in accordance to the requirements of (A) class reserves prescribed in “Classification and guideline of mineral resources and reserves of deposits” that practiced in Mongolia. Based on exploration results, the estimated Proved (A) class reserve of the deposit has to be sufficient reserves to cover the initial investment of the mining enterprise.

Measured reserves (B): The Measured (B) class reserve is calculated in an area of the 1st and 2nd groups of deposits subjected their detailed study area. Boundary of the reserve blocks shall be bordered with line connecting excavation workings and boreholes.

On the basis of detailed studies on the basic parameters like as thickness ranges of the ore-bodies and distribution pattern of major useful components, as well as identification of mining-geological condition, the border of blocks belonging to the Measured (B) classification can be contoured within frame of limited extrapolation.

Also, it can be considered as Measured (B) class, if the part of the deposit locating under operation has been getting prepared or ready for mining excavation in results of completing exploration and mining excavation works. In addition, the Measured (B) class reserves are stated in accordance to the requirements of (B) class reserves prescribed in “Classification and guideline of mineral resources and reserves of deposits” that practiced in Mongolia.

In case of 2nd group of deposit, major part of the reserves shall be estimated in Measured (B) classification.

Indicated reserves (C): The Indicated (C) class reserves are estimated in that part of deposit, where the exploration grid density allowed meeting the requirements to estimate the reserves in C-classification. For the area of the deposit that subjected to reserve estimation in Indicated (C) classification, the geological information and results have to be confirmed by the result of the detailed survey of the deposit, and for the mine operation area - by the results of exploitation of the deposit. In addition, boundary of area that subjected to reserve estimation in Indicated (C) class can be configured out along with lines connecting data of exploration workings and boreholes, and extrapolation lines taking in account the data of geological setting, morphology changes and geophysical survey of deposit.

The Indicated (C) class reserves are estimated in accordance to the requirements of (C) class reserves prescribed in “Classification and guideline of mineral resources and reserves of deposits” that practiced in Mongolia.

In case of 3rd group of deposit, major part of the reserves shall be estimated in Indicated (C) classification.

The evaluation of Identified resources (P_1) category is carried out on ore bodies explored by a few excavation and drillholes as well as marginal and depth parts of ore contacted with reserve estimated ore blocks. The boundary of the ore block selected for P1 category reserve estimation is delineated by using Indicated (C) category grid density or on the basis of available data resulted from geologic settings ang geophysics.

6.4. Feasibility studies precede mining operation on the basis of geological reserves estimated. In results of the feasibility study completion, part of the geological reserves located within frame of the deposit and remaining after dedication of mining waste and pollution is presenting the production reserves, which is divided into Proved (A’) and Probable (B’) reserves according to requirements of “Classification and guideline of mineral resources and reserves of deposits”.

Proved (A’) production reserve is based on the geological reserves of mineral resources of Proved (A) and Measured (B) classifications; and on background of pilot test results selecting mining technics and technology, relevant assessments and ore technology features; and defined in details the engineering solutions, environmental and occupational safety taking in account hygiene, rights, human resources, management organizational structure, supply infrastructure, social and economic services, and economic efficiency calculations and related factors in accordance to "Feasibility study for deposit exploitation of mineral resources".

Probable (B’) production reserve is based on geological reserves of mineral resources of Measured (B) and Indicated (C) classifications; and on background of pilot test results selecting mining technics and technology, relevant assessments and ore technology features; and defined in details the engineering solutions, environmental and occupational safety taking in account hygiene, rights, human resources, management organizational structure, supply infrastructure, social and economic services, and economic efficiency calculations and related factors in accordance to "Feasibility study for deposit exploitation of mineral resources".

6.5. In case of exploiting deposits, the ore reserves in the stripped, prepared for mining, and ready-to-extract, as well as hosted in the protection pillars of preparatory excavations, will be classified and estimated according to their respective resource levels.

6.6. The ore reserves in protected areas of reservoirs and forest, rivers, settlements, building facilities, agricultural objects, strictly protected areas, protected zones of natural, historical and cultural sites, shall be estimated and included to the resource according to approved standard.

6.7. Comparing information on the explored reserve, existing condition of ore body, shape, thickness, internal structure, and mineral content should be considered in accordance with established regulation to monitor whether previously registered reserves are being fully mined in the exploiting deposits and evaluate the confidence of newly calculating reserves.

The compared data file required to include the contours of, previously registered reserves, deducted reserves (of which extracted and remained in protection pillars), excluded one because of unverified, increased reserves as well as information on registered reserve in the State Reserve Balance (including the balance of previously recorded reserves) and reserve contours.

A table of reserve balance/movement for the ore bodies as a whole and for each resource category has been prepared. The changes in the completing exploration of the reserve discussed and recorded at the Mineral Resources Professional Council (MRPC) meeting should be reflected in the balance of ores and metals within the deducted reserves. The wastes from mining and transportation, product yields and wastes during the ore processing, should be shown. The results of the comparison should contain the graphics showing the changes in the mining and geological conditions of the deposit.

If the exploration data is confirmed by the mining as a whole, or if small discrepancies which are not affecting the technical and economic parameters of the mining operation, the results of geology-surveying can be used to compare exploration and exploitation data.

According to the mineral license holder, if the reserves and ore quality discussed and registered at Mineral Resources Professional Council (MRPC) meeting are not confirmed during the exploitation and previously proved parameters and reserves still need correction coefficient, and completing exploration and mining stage exploration are required to be done in order to perform re-estimation and evaluate the reliability of the survey results.

When analyzing the results of the comparison, it is necessary to establish the changes during completing exploration and mining stage exploration of reserve estimation parameters (reserve-estimated area, grades of useful components, ore body thickness, mineralization coefficients, volume weight, etc.) reserves and ore quality and explain the reasons for these changes

6.8. In recent years, the method of geostatic modeling (Kriging) has been widely used to study the spatial distribution patterns of the studied properties (content of useful components, thickness of ore intersections) in the reserve estimation of ore deposits.

The effectiveness of the using the Kriging method are largely related to the quantity and quality of primary exploration data and the analysis and modeling methods of the primary data to be adapted to the geological features (major calculation values, distribution behavior, trend, anisotropy, effect of structural contact, structure and quality of experimental variogram, search ellipsoid parameters etc.) of the explored deposit.

When using the Kriging method, the number and density of exploration grid should be sufficient to substantiate the optimal interpolation equation (at least a dozen exploration intersections in two-dimensional modeling, and at least a few hundred sampling results in three-dimensional modeling).

It is recommended that studies of spatial variables be conducted in areas that have been studied in detail. The variogram calculations are performed in large mineralized zone-shaped deposits with grouped specimens of the same length as the open pit bench height, and with sample intersections (intervals) if grouped specimens are not available for vertical change studies.

When establishing a block geostatistic model of the deposit, the maximum possible size of elementary estimation block is selected depending on planned mining technology, while the minimum possible size (the minimum unit block) is selected depending on density of exploration grid (it is not recommended to take the size of the sides of an elementary block less than 1/4 of the average density of the exploration grid).

The results of resource estimates can be presented in two ways:

1. When calculating identical equally-oriented blocks on a grid, tables of calculation parameters are compiled for all elementary blocks together with the values of the kriging dispersion,

2. When calculating large geological blocks, each block must be spatially referenced and a list of samples included in the zone of influence should be made.

All vector data (sampling data, coordinates of samples or ore intersections, analytical expressions of structural function-variograms, etc.) should be presented in formats available for examination using the most common software packages (Excel, Access, Surpac, Micromine, Leapfrog etc.).

Models of systemised transformations, trends and variograms, other parameters should be presented in an analytical and written form.

Geostatistical method applied in reserve estimation is considered as the best way to determine the most accurate evaluation of average economic content throughout a particular block, ore body or a deposit. Besides, it can provide the possibility to reduce ore contact - related errors in complex morphology and interior structure and to optimize the ore-processing technology. The results of geostatistic models and interpretation must be verified by comparing with traditional reserve estimation results for representative blocks and a whole deposit.

6.9. In case of reserve estimation completed by using specific software, the primary data file (exploration coordinates, borehole inclination data, lithology, stratigraphic contacts, sampling results etc.), calculations for error corrections, and model construction results (block sections, reserve boundary, plan map or reserve estimation parameters based on geological sections, vertical and horizontal projection of ore body, block sections and workface sections) are possible to be checked, revised and updated. The produced documents and computer-generated graphics must meet the requirements of this type of document.

6.10. The reserve estimation on accompanied minerals and compound is made in compliance with the relevant rules.

6.11. A report incluing resource estimation should be processed according to “Regulations on Mineral prospecting and exploration activities” approved by order #A/20, 2018 by the Mining & Heavy Industry Minister.

Seven. Study degree of deposit

According to the “Guidelines for classification of mineral resources and deposit reserves” any deposits are classified into following two items: evaluated deposits and explored deposits.

The study degree of the evaluated deposit determines the feasibility of continuing exploration work at the object, while for the explored deposit, it determines the readiness of the deposit for industrial mining.

7.1. At the assessed deposits of aluminum ores, their industrial value and the feasibility of carrying out the exploration stage of work should be determined, the general scale of the deposit should be identified, the most promising areas should be identified to justify the sequence of exploration and subsequent development.

The results of the geology-exploration work of the evaluated aluminum deposits should determine whether there is a need for an exploration stage, the potential value of the deposit, the overall size of the deposit, and the prospective areas that justify further exploration and subsequent mining operations should be identified.

The standard parameters to be used in resource estimates should be based on a preliminary feasibility study of a temporary exploration standard developed on the basis of reports on the results of the evaluation of newly discovered deposits, and should be sufficient to conduct a preliminary geological and economic assessment of the deposit.

The mineral exploration and mining license holders establish the assumptions about mining methods, systems, and potential production levels based on analogous projects by an aggregate basis.

The enrichment technological schemes, the possible yield and quality of products will be determined based on laboratory pilot test assuming full utilization of raw materials.

The capital costs for the construction of the mine, the cost of marketable products and other economic indicators should be determined according to aggregated calculations based on analogous projects.

When assessing the industrial significance of solid mineral deposits, the issues of household and drinking water supply for mining enterprises are preliminarily characterized based on existing, explored and probable sources of water supply.

For the evaluated deposits, experimental extracting production and processing may be carried out in order to conduct a detailed study of the shape of the ore bodies and chemical composition and the technological scheme of ore beneficiation. This should be carried out in areas that are representative of the majority of the deposit and contain the most common ore bodies in the deposit, during the period up to three years with the official permission from the relevant authorities of mining and natural environment issues. The scope and timing of this work should be agreed with Mongolia's professional inspection bodies in charge of ecology, technology and nuclear issues.

The need for experimental extracting production must be justified in each case by defining its purpose and objectives.

The experimental extracting production has to be made to clarify the more specific characteristics of the geologic settings of the ore body (change in internal structure and shape), and the proper mining-geological and geo-technical conditions, as well as the ore enrichment and processing methods (identifying natural and production types of ore and determine their ratio, enrichment character and semi-industrial test). These issues can be solved when the ore bodies area revealed by excavations with high depth and length. This experimental work will be carried out when introducing new methods in mining of mineral resource such as during borehole extraction of loosened and sparse ores and mining-out new non-traditional types of ore. In addition, in the case of large and very large deposits, it is necessary to test and improve the technological scheme developed in small concentrators before the construction of large factories.

7.2. In order to implement the conditions and relevant procedures for putting the explored deposits into production, to obtain necessary and sufficient information for the feasibility study, and to develop a project to build a mining plant and renovate such plants, the deposit reserves, ore quality, technological parameters, hydrogeological and mining -technical and ecological conditions should be studied through boreholes and excavations.

The explored deposits must meet the following requirements at the level of study:

- It is possible to classify most of the resources in the category corresponding to the complexity group of the geological structure of the deposit;

- Industrial type of mineral resources and technological properties of ore sorts should be studied in detail to develop an optimal mode of ore technology processing, extract complex minerals that are of industrial importance, to determine the trend to use factory waste, and to provide the ratinal version of storage;

- By-products and useful component-containing complexes such as cover sediment and underground water should be sufficiently studied and evaluated to the extent sufficient for estimating their reserve, classifying them as geological reserve or resources based on standard, and determining their quantity and potential use.

- Hydrogeology, engineering-geology, geocryology, geo-technical and other natural conditions should be studied in sufficiently accurate providing the initial data necessary for the project development of the deposit, taking into account the requirements of environmental legislation and safety of mining operations;

- The accuracy of data on the geological structure, forming condition and morphology of ore bodies, the quality and quantity of reserves, should be confirmed at the detailed areas that can represent the entire deposit, as well as in each specific case, the size and location of this area should be determined depending on their geological characteristics;

- To give recommendation with appropriate normative documents to minimize and mitigate the expected negative ecological consequences considering the potential impacts on the environment due to the deposit exploitation;

- The conditional parameters to be used for reserve estimation, should be established on the basis of feasibility study that allow for determination of industrial significance and scale of the deposit;

The miner of the subsoil and experts of Mineral Resources Professional Council considering the level of business risk shall determine the appropriate ratio of different reserve category. The expert of Mineral Resources Professional Council will determine and decide as recommendation the each case of possibility to exploit the Probable (C) category reserve fully or part to develop the deposit-extracting plan. In this case, the solving factors are features of geological setting of ore bodies, their thickness, characteristics of mineralization distribution within them, assessment of random errors of exploration (methodical, technical tool, sampling and analytical etc.) and consideration of exploration and exploitation experience of similar deposits.

The explored deposits are considered as ready for the possession of the industrial purposes both after issues in these recommendation have been implemented and the reserve have been registered in accordance with established regulations.

Eigth. Re-estimation and registration of reserve

Re-estimation and registration of reserves in accordance with the established procedure is carried out at the initiative of the subsoil user, as well as control and supervisory organizations in cases of a significant change in ideas about the quality and quantity of reserves of the deposit and its geological and economic assessment as a result of additional exploration and mining operations.

At the initiative of the license holder, re-estimation and registration of reserves are carried out to the deposit in following cases due to the economic situation has deteriorated dramatically:

- In case of substantial non-confirmation of previously approved reserves and its certain part and their quality;
- In case of steady fall (20% or more) of the product price in significant value when the production level of prime cost is stable;
- Changing industry requirements for the quality of mineral raw materials;
- When the total amount of reserve during completing, mining stage exploration and mining operation, the unapproved amount of deducted and deductible reserves, and also the amount of reserve that cannot be extracted due to technical and economic reasons, are higher (20% and more) and lower than a normative of regulation on the deduction of mineral reserves from the balance sheet of the mountain industry.

At the initiative of the supervisory and professional inspection organizations, the re-estimation and registration of reserves are carried out to the deposit in following cases such as the license holder (state)'s right has been violated, and especially unreasonable reductions in the taxable base:

- Increase in deposit's reserves, compared with previously approved or registered by 30% and more;

- a significant and stable increase in world prices for the products of the enterprise (more than 30% of the conditions laid down in the condition of feasibility studies);

- development and introduction of new technologies that significantly improve the production capacity;

- Identifying in the ores or host rocks, valuable components or harmful impurities that were not previously taken into account when assessing the deposit and designing the enterprise.

Economic issues of production due to temporary causes (complication in geology, technology, hydrogeology and mining conditions, temporary drop of price in the world market etc.,) are solved by the assistance of conditional mechanism of exploitation so, re-estimates, re-approval and registration of reserves are not required.

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