METHODICAL RECOMMENDATION

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

(RARE EARTH ELEMENT, NIOBIUMAND TANTALUM)

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

RARE EARTH ELEMENT, NIOBIUM AND TANTALUM

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The Guideline of the "METHODICAL RECOMMENDATION…" will 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 rare earth element, niobium and tantalum.

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One. Preface

The recommendation is compiled in accordance to a number of provisions of relevant law, decrees and regulations as following: “State policy on the mineral sector approach”, provision #16 of the Minerals law, “Action program to be implemented by the government of Mongolia in 2016-2020”, “Regulations on Mineral prospecting and exploration activities” approved by order #A/270, dated February 05, 2019 by the Mining & Heavy Industry Minister, as well as a provision approved by a Mining Minister order #203 dated on September 11, 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”. It also specifies how properly use the classification of mineral resources and mineral reserves of niobium, tantalum and rare earth element deposit.

The recommendation provides the practical assistance for entities who own exploration and mining licenses, geologists, prospectors, miners and niobium, tantalum and rare earth element mining organizations and companies to compile a final report on reserve estimation, to have the estimated reserves registered to the state mineral resource register and update reserve data.

As a result of multi-stage geological mapping and exploration research conducted in the territory of Mongolia, 6 medium and small deposits of rare earth element and more than 80 medium to small scale occurrences with niobium, tantalum and rare earth element mineralization have been discovered. In terms of ore genesis and ore type as well as ore body morphology, rare earth element deposits in Mongolia belong to main types that are distinguished for exploration purposes in the worldwide.

This recommendation is intended to help geologists carefully observe the differences between the ore types of niobium, tantalum and rare earth element deposits, and select appropriate exploration methodology which fits ore type, processing technology and main ore mineral etc. In recent years, with the advancement of technology, it has become possible to study all types of ore deposits in the course of exploration, in conjunction with other methods as of geophysical surveying and geotechnical measurements.Consequently, there is an increasing need for pre-study at the exploration stage to ensure that the quality control of the samples used for geostatistical analysis of resource estimates is aimed at the optimal and complete exploitation of the deposit

Two. Basic concept

2.1. Rare earth element

2.1.1. General introduction of rare earth element, usage and importane

The rare earth elements are a set of 17, that includes 15 elements of the lanthanide group (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) from lanthanum (57) to lutetium (71) in the periodic table of chemical elements together with yttrium (Y) and scandium (Sc).

Rare earth elements are nearly indistinguishable lustrous silvery-white soft heavy metals, which geochemically similar to each other, so they often coexist in nature and participate together in any geochemical activity in the nature. The dencity of rare earth element ranges from 4.48 g/cm^3 (Y) to 9.32 g/cm^3 (Tu), its melting point varies from 804°C (cerium) to 1550°C (Thulium), and boiling point ranges from 1700°C (Europium) to 4515°C (lanthanum), rare earth elements form oxidation state of +3 in the nature. Based on the ionic radii rare earth elements are subdivided into heavy rare earth (HREE) and light rare earth (LREE) groups. Light rare elements are named as cerium group and includes elements such as lanthanum (La^{57}), cerium (Ce^{58}), praseodymium (Pr^{59}), neodymium (Nd^{60}), promethium (Pm^{61}), while Heavy rare earth elements are called yttrium group elements and contain samarium (Sm^{62}), europium (Eu^{63}), gadolinium (Gd^{64}), terbium (Tb^{65}), dysprosium (Dy^{66}), holmium (Ho^{67}), erbium (Er^{69}), thulium (Tm^{69}), ytterbium (Yb^{70}), luthetium (Lu^{71}) and yttrium (Y^{39}). HREE group includes yttrium because of its ionic radius and geochemical property is very similar. In recent years, there has been a tendency to divide it into three categories: light (cerium), medium (samarium), and heavy (erbium) groups.

Lanthanum (La^{57}) isis a soft, ductile, silvery-white metal that tarnishes slowly when exposed to air. It is the eponym of the lanthanide series, a group of 15 similar elements between lanthanum and lutetium in the periodic table, of which lanthanum is the first and the prototype. Lanthanum is traditionally counted among the rare earth elements. The usual oxidation state is +3. Lanthanum has no biological role in humans but is essential to some bacteria. It is not particularly toxic to humans but does show some antimicrobial activity.

Cerium (Ce^{58}) is a soft, ductile, and silvery-white metal that tarnishes when exposed to air, and it is soft enough to be cut with a steel kitchen knife. Cerium is the second element in the lanthanide series, and while it often shows the +3 oxidation state characteristic of the series, it also has a stable +4 state that does not oxidize in water. It is also considered one of the rare-earth elements. Cerium has no biological role in humans and is not very toxic. It is contained in minerals such as allanite, orthite, monazite, bastnaesite, cerite and samarskite.

Praseodymium(Pr^{59}) is the third member of the lanthanide series and is traditionally considered to be one of the rare-earth metals. Praseodymium is a soft, silvery, malleable and ductile metal, valued for its magnetic, electrical, chemical, and optical properties. It is too reactive to be found in native form, and pure praseodymium metal slowly develops a green oxide coating when exposed to air. It is contained in monazite and bastnaesite together with other rare earth elements

Neodymium (Nd^{60}) is hard, slightly malleable silvery metal quickly tarnishes in air and moisture. When oxidized, neodymium reacts quickly to produce pink, purple/blue and yellow compounds in the +2, +3 and +4 oxidation states.It is present in significant quantities in the ore minerals monazite and bastnäsite. Neodymium is not found naturally in metallic form or unmixed with other lanthanides, and it is usually refined for general use. Although neodymium is classed as a rare-earth element, it is fairly common, no rarer than cobalt, nickel, or copper, and is widely distributed in the Earth's crust.

Promethium (Pm^{61}) is extremely rare, with only about 500–600 grams naturally occurring in Earth's crust at any given time. Promethium is one of only two radioactive elements that are followed in the periodic table by elements with stable forms, the other being technetium.

Samarium (Sm^{62}) is a moderately hard silvery metal that slowly oxidizes in air. Being a typical member of the lanthanide series, samarium usually assumes the oxidation state +3. The last compound is a common reducing agent in chemical synthesis. Samarium has no significant biological role but is only slightly toxic.

Europium (Eu^{63}) is the most reactive lanthanide by far, having to be stored under an inert fluid to protect it from atmospheric oxygen or moisture. Europium is also the softest lanthanide, as it can be dented with a fingernail and easily cut with a knife. When oxidation is removed a shiny-white metal is visible. Europium has no significant biological role and is relatively non-toxic compared to other heavy metals. Most applications of europium exploit the phosphorescence of europium compounds.

Gadolinium (Gd^{64}) is a silvery-white metal when oxidation is removed. It is only slightly malleable and is a ductile rare-earth element. Gadolinium reacts with atmospheric oxygen or moisture slowly to form a black coating. It is found in nature only in an oxidized form. When separated, it usually has impurities of the other rare-earths because of their similar chemical properties.

Terbium (Tb^{65}) is a silvery-white, malleable, ductile, and soft enough to be cut with a knife. Terbium is a fairly electropositive metal that reacts with water, evolving hydrogen gas. Terbium is never found in nature as a free element, but it is contained in cerite, gadolinite, monazite, xenotime, and euxenite.

Dysprosium (Dy^{66}) has metallic silver luster. Dysprosium is never found in nature as a free element, though it is found in various minerals, such as xenotime, fergusonite euxenite etc. Naturally occurring dysprosium is composed of seven isotopes.

Holmium (Ho^{67}) is a relatively soft and malleable silvery-white metal. It is too reactive to be found uncombined in nature, but when isolated, is relatively stable in dry air at room temperature. However, it reacts with water and corrodes readily and also burns in air when heated.

Erbium(Er^{68}) is a silvery-white solid metal when artificially isolated, natural erbium is always found in chemical combination with other elements. It is originally found in the gadolinite mine in Ytterby in Sweden, from which it got its name.

Thulium (Tm^{69}) is the secondleast abundant of the lanthanides, after radioactively unstable promethium which is only found in trace quantities on Earth. It is an easily workable metal with a bright silvery-gray luster. It is fairly soft and slowly tarnishes in air. Despite its high price and rarity, thulium is used as the radiation source in portable X-ray devices, and in some solid-state lasers. It has no significant biological role and is not particularly toxic.

Ytterbium (Yb^{70})is a soft, malleable and ductile chemical element that displays a bright silvery luster when pure. It is readily dissolved by the strong mineral acids. It reacts slowly with cold water and it oxidizes slowly in air. In aqueous solution, like compounds of other late lanthanides, soluble ytterbium compounds form complexes with nine water molecules.

Lutetium (Lu^{71}) is a silvery white metal, which resists corrosion in dry air, but not in moist air. Lutetium is the last element in the lanthanide series, and it is traditionally counted among the rare earths. Lutetium is generally considered the first element of the 6th-period transition metals by those who study the matter, although there has been some dispute on this point.

Yttrium (Y^{39}) is a silverymetallic transition metal. It is chemically similar to the lanthanides and has often been classified as a "rare-earth element".Yttrium is almost always found in combination with lanthanide elements in rare-earth minerals, and is never found in nature as a free element. The most important uses of yttrium are LEDs and phosphors, particularly the red phosphors in television set cathode ray tube displays.It is also used in the productionof electrodes, electrolytes, electronic filters, lasers, superconductors, various medical applications, and tracing various materials to enhance their properties.

Scandium (Sc^{21}) is a silverywhite metallicelement, it has historically been classified as a rare-earth element, together with yttrium and the lanthanides. Scandium is present in most of the deposits of rare-earth and uranium compounds, but it is extracted from these ores in only a few mines worldwide. The properties of scandium compounds are intermediate between those of aluminium and yttrium. A diagonal relationship exists between the behavior of magnesium and scandium, just as there is between beryllium and aluminium.

Rare earth metals are chemically very active and can interact with almost all elements at relatively low temperature environment.It combines with oxygen (O), sulfur (S), hydrogen (H), carbon (C), nitrogen (N), phosphorus (P), and halogen elements to form oxides, sulfides, and carbides. Metal lanthanum, cerium, and prometium are easily oxidized in air, but in other side haevy REE are more stable.Rare earth elements have been used for a variety of purposes since their discovery, but until 1965 their use was relatively limited.Since the mid-1960's, started using of rare earth elements in color television screens, especially europium is used for adjusting tool of color television screen and led to increase use of REE. Recent years, rapid development of high technology and the discovery of new uses for metals, the number of products that contain rare earth elements has been increasing over the last 20 years and itsuse (Table 1) is abruptlyincreased. For eaxample: Twenty years ago, cell phones were used by a small number of people, but today they are used by about five billion people.

Table 1. Use of REEs by each metal type

REEs	Main uses
Lantanium (La)	Electric and dual-engine vehicles, cameras, laptops, rechargeable NiMH batteries, and anti-glare detergents are widely used
Cerium (Ce)	It is used in glass, metal, precious stones, computer microdistricts, transistors and electrical equipment, and inverters to reduce air pollution

Prazeodium (Pr)	Produces strong magnets with neodymium. Used for strong welding, sun protection and plastic products
Neodium (Nd)	The strongest magnet was created by combining prazeodium. This magnet is used in many electrical and automotive products
Prometium (Pm)	A portable X-RAY instrument is used to produce light that is controlled by the adsorption of light and has the ability to convert light into electricity
Samarium (Sm)	Initially, X-rays and laser technology were used in the production of permanent magnets. In the field of nuclear energy, neutron absorbers are widely used in the production of strong and stable magnets, as well as optical absorbers.
Europium (Eu)	Flight costing and color television are used by the industry. Today, television screen color activators, European-coated plastics, laser technology, and ceramics are used in the nuclear power industry
Gadolinium (Gd)	The use of MRI equipment has made it possible to identify tumors and diagnose cancer. Used to monitor nuclear fission during nuclear reactions. Gadolinium bait grenades are used in shortwave and on silver television screens
Terbium (Tb)	Widely used for lighting. In the case of a mixture of zirconium with the activation of the green color of terbium, it acts as a balancer for the fuel cell
Dysprosium (Dy)	Neodymium-iron-boron is the most widely used in the production of permanent magnets. These powerful magnets are used in twin-engine motors, for various electrical purposes, and to capture neutrons during nuclear reactions. Dysprosium-nickel cement is used to reduce heat released by nuclear reactors. It is also used in the production of laser materials with GHE and vanadium
Holmium (Hm)	It is released during the separation of metal-calcium anhydride chloride or fluoride. It is widely used in the production of magnetic materials and in the production of ceramics and laser materials
Erbium (Er)	To change the color of the glass, use a wide range of medical and dental laser equipment. In photo filters, erbium trichloride is used for evaluation and sunscreen
Tulium (Tm)	It is difficult to distinguish, and its use is limited. 169Tm isotope portable X-ray instrument; 171Tm isotope energy source
Ytterbium (Yb)	The chemical properties of this element have not been fully studied and in limited use. Used in the metallurgical industry to improve the mechanical skills of steel
Lutetium (Lu)	The lutein nucleus is used in accelerators, alkalisation, and polymerization to emit radiation after neutron thermal reactions
Yttrium (Y)	Widely used as a luminaire. Used in combination with zirconia to cover high-temperature spacecraft coatings. Recently, it has been used in the production of LED screens. It is also used in the manufacture of electrodes, lasers, transmitters and medical devices
Сканди(Sc)	Alloy combined with aluminum is widely used in the manufacture of spacecraft. The latter alloy is used to make the lightest golf club

2.1.2. General introduction and rare earth element bearing main minerals

There are 129 minerals containing REE, 51 minerals of which are enriched in yttrium-group HREEs and 78 mineralis are mainly enriched be cerium-group LREEs. Main LREE bearing minerals are bastnaesite [(Ce, La ...)(CO_3)F], monazite [(Ce,La ...)PO_4], partly pyrochlore [(Na,Ca,Ce. . .)$_2Nb_2O_6$F] and other minerals. Yttrium group HREE bearing minerals are xenotime (YPO_4), yttro-synchisite [Y,Ca(CO_3)$_2$F] and other minerals (Table 2).Үүнээс гадна апатитаар фосфорын бордоо хийх явцад ГХЭ–ийг гаргаж авдаг. In addition, REEs are extracted during producing phosphorus fertilizer from apatite. More than 20 minerals are main producing minerals of REE. General features of main REE bearing minerals, mentioned in the Russian niobium, tantalum and REE exploration methodological guideline, is given on Table 2 and REE bearing minerals which are mined from main REE producing deposits of world are given in Table 3.

Table 2. Main REE bearing minerals

Minerals	Chemical composition	Content of rare earth total oxide, %	Accompanying elements	Density, g/cm^3
Monazite	$CePO_4$	Σ Ce_2O_3<35; ThO_2<31	–	4.9–5.5

Xenotime	YPO_4	Σ Y_2O_3<61	U, Tb, TR	4.4–4.6
Churchite	$YPO_4 \cdot 2H_2O$	Σ Y_2O_3<51	TR	3.1–3.3
Bastnaesite	$CeCO_3F$	Σ Ce_2O_3 до 75	TR, Th	4.4–5.2
Parisite	$Ce_2Ca[CO_3]_2F_2$	Σ Ce_2O_3<60; Y_2O_3<10	TR, Th	4.3–4.4
Yttro-synchisite	$YCa[CO_3]_2F$	Σ Y_2O_3=44–47	Th, TR	3.6–3.7
Fergusonite	Y(Ta, Nb)O_4	ΣY_2O_3=33–44;Ta_2O_5=4–9; Nb_2O_5=38.0–51.6	U, Th, TR	5.5–6.0
Euxenite	Y(Nb, Ti, Ta)$_2$(O, OH)$_6$	ΣY_2O_3=16.3–27.8; Nb_2O_5=8.8–41.4; Ta_2O_5=1.0– 47.3	U, Th, TR	5.0–5.9
Gagarinite	(Na, Ca)$_3YF_6$	Σ Y_2O_3=35–48	U, Th	4.2–4.5
Yttro-Fluorite	(Y, Ca)F_{3-x}	Σ TR_2O_3=18–20	–	3.5–3.8

Table 3. REE bearing minerals in main producing mines of theworld,

№	**Mineral**	**Chemical composition**	**Content of REEoxide, %**
1	Bastnaesite (Ce)	(Ce,La)($C0_3$)F	75
2	Monazite (Ce)	(Ce,La,Nd,Th)$P0_4$	65
3	Parisite (Ce)	Ca(Ce,La)2(C03)$_3F_2$	61
4	Xenotime	$YP0_4$.	61
5	Gadolinite (Ce)	(Ce.La,Nd,Y)$_2Fe^{2+}Be_2Si_2$010	60
6	Yttro-cerite	(Ca.Ce,Y.La)F_3,n$H_2$0	53
7	Synchisite Ce)	Ca(Ge, LA)($C0_3$)$_2$F.	51
8	Huangoit (Ce)	BaCe($C0_3$)$_2$F.	39
9	Allanite (Ce)	(Ce,Ca,Y)2(Al,Fe3+)$_3$(SiO4)3OH.	38
10	Britholite (Ce)	(Ce,Ca)5(SiO_4,PO_4)$_3$(OH,F)	32
11	Cebaity (Ce)	Ba_3Ce_2(C03]$_5F_z$.	32
12	Fluorencite (Ce)	Ce Al_3(P04}$_2$(OH)$_6$.	32
13	Loparite	(Ce,La,Na,Ca.Sr)(Ti,Nb)0_3	30
14	Euxenite (Y)	(Y.Ca.Ce,U,Th)(Nb,Ta,Ti)$_2$O6	24
15	Eudialite	Na_4(Ca,Ce)2Fe^{2+},Mn,Y)Zr$Si_8$0$_{22}$(OH,CI)$_2$(?).	9

2.1.3. Production of REEs and its perspective

According to the US Geological Survey open file report, as of December 2018, the world's total REE reserves are about 120 million tons, of which China leads with 36.7%, Brazil with 18.3% and Vietnam with 18.3%. In terms of production of REE, the world produces a total of 170,000 tons of REE per year, of which China produces 120,000 tons making 70.6%, Australia 20,000 tons making 11.8%, and the United States 15,000 tons making 8.8%.

Main part of world's REE reserve is owned by a few countries, even though Chine owns 1 third of world’s REE reserve and still leads by its REE production and reserve. In the United States, the Mountain Pass deposit is a major producer which was shut down in 1998 but re-opened in 2018. In addition to Mountain Pass deposit, exploration work is undergoing on a number of REE deposits and occurrences, including Bokan Mountain, Bear Lodge and Round Top. The U.S. Geological Survey has used a hyper spectrum method on the exploration project in Alaska and discovered new promising area of REE mineralization (Wilburn and Karl, 2018).India has about 5% of the world's REE reserve which is concentrated at the coastal placer deposit containing ilmenite, sillimanite, garnet, zircon, monazite and rutile.In recent years, the Indian Geological Survey has been focusing on REE prospecting and exploration projects of alkaline intrusive, carbonatite, skarn, pegmatite and greisen mineralizations. Coastal and inland placer deposits containup to 11.935 million tonnes of monazite reserves in 2016, 30% of which are in the Andra Pradesh group of placer deposits.

World price for rare earth metals and oxides is sharply increased since 2005, but have been declining since the first quarter of 2012. Researchers studying unstability of REE price explains that the rise price is due to China's dominance on production of REEs restrictions on metal exports. However, the decrease of prices and recent stability is explained that it is related with key consumer countries stocked enough required metal, and in some countries REE mines have started operating and also some country started to recycle this metall. Although there is a tendency to be supplied by total REO, but in a certain extent, it is expected that the demand for HREE will be high risk and prices will likely rise again. Although REE prices are expected to stabilize in the future, some analysts believe that there may be a sudden increase in REE prices due to global economic growth in consequence with global population growth. In China, a major producer of REE, there is no denying that prices may rise in recent years due to the deteriorating environmental and socio-political situation, as well as rising wages.

Rare earth elements remain the main raw material for the production of green technology, electronics and military equipment. The use of the 17 metals in the REE varies, and while the use of some elements decreases, the use of heavy rare earth elements, such as dysprosium, neodymium, and europium increases. It is difficult to predict the future use of REE, but it is proposed that to increase between 5 and 9% over the next 25 years (Alonso et all., 2012). Due to the development of green technology, the price of dysprosium, which is widely used in the production of wind turbines and electric motors, may increase significantly. At current consumption, it is estimated that 105,000 tons (± 15%) of REE oxide per year is required (Hatch, 2012; Alonso et al., 2012). Permanent magnets, metal alloys, catalyst manufacturing, and polishing are the main applications of LDCs. Currently, permanent magnets made of elements such as neodymium, praseodymium, and samaritan (in addition to dysprosia and terbium) are the strongest and lightest, so they are in high demand in the world market. Taking into account all types of GHG consumption, it is projected to grow by 5-8.6% per year, and the model needs to be modeled until 2025, and the total annual GHG consumption is expected to reach 210,000 tons by 2025

According to a study of global energy sources, energy consumption is expected to grow by 13% annually until 2035. Of course, combustible minerals will remain the main raw material, accounting for three-quarters of total energy by 2035, and renewable energy is proposed to reach about 10%. Thus, with the development of environmentally friendly green technology, the demand for REE is likely to continue to grow

2.1.4. Genesis and mineralization characteristics of REEs

Due to their large ionic radii, REEs are unlikely to enter the internal structure of the major rock-forming minerals during the crystallization of silicate magma, therefore they usually remains in the residue of silicate melt, and in the final stage of crystallization, they concentrate to minerals such as zircon, garnet and apatite. Pegmatites of granitic magma tend to be enriched by REEs.

REE mineralization is genetically associates with within plate geodynamic environment, and form along with pull apart faluts related with extentional tectonic and partly in the zone of asthenopheric upwelling. In such tectonic environment, due to the thinning of the lithosphere, the pressure decreases and the magma input, which originated in the deep mantle, and started to cool down and forms alkaline-mafic intrusive bodies, which are genetically related to REE deposit.

Some researchers analyzed the current geodynamic environment of large REE deposits around the world and gave a suggestion that their distribution occurs in conditions such as ancient basin, continental rift, orogenic setting and weathering zone (Chakmouradian et all., 2012).

Due to the development of high technology and the increasing use of REEs, intensive research to identify these metal sources worldwide was conducted intensively in 2005-2011, and the US Geological Survey reported on mineralization and its prospects in the United States and around the world (Keith et all, 2010). According to the US Geological Survey, REE mineralization is classified into nine main types of origin and examples of its representative deposits are given below (Table 4).

Alkaline related REE mineralization mainly associates with alkaline magma, which has very complex source and its mineralization model is not clear, still under studying. Alkaline related REE mineralization often associated with zirconium, niobium, strontium, barium, and lithium, and is difficult to systematically determine the genetic relationship. Carbonatites are very rare, occurring in only 527 locations worldwide (Woolley and Kjarsgaard, 2008). The iron-oxide gold-copper deposit is a unique new type of deposit which has discovered since the discovery of the Olympic Dam in the 1980s. Although similar deposits are common throughout the world, their REE content is low, while the Olympic Dam deposit has significant reserves. Pegmatites are formed around the marginal part of large granite intrusive bodies, and they have a very complex variety of compositions and are generally not economically significant because they are generally small in size.

Claymax-type molybdenum porphyry deposits partly show higher content of REE in some exploration level, but its distribution is very irregular, so its perspective is unclear. Weathering results in the erosion of rockand rock mass, containing rare earth elements from REE mineralized areas ordeposits and derives to plain enviroment and accumulate to form placer deposit. In particular, the main source of monazite and xenotime is placer deposit. Coastal black sands form Ilmenite-magnetite and tin placer deposits and they contain significant amount of monazite as a by-product. In hot and humid climates, surface of REE mineralized rocks or deposits affected by deep chemical weathering and forms iron and aluminum-iron-enriched residual surfaces, which is enriched by REE, especially high enrichment of HREE.In Montenegro found that some aluminum-rich sediments accumulated in the karst caves in the limestone are enriched with REE, but their economic significance is currently unknown (Maksimović, 1995).

Table 4. Genetic types of REE mineralization (Keith, 2010)

Genetic type	**Sub types of REE mineralization**	**Example of main representative deposits**
Alkaline intrusive related	Magmatic (alkaline-mafic)	Lovosero, Russia,
	Pegmatite vein (alkaline-mafic)	Khibin alkaline massive, Russia
	Pegmatite vein (ultra alkaline)	Motzfeld, Greenland
	Hydrothermal vein and stock work	Idaho Lemhi, USA
	Volcanic	Brockman, Western Australia

	Albitite metasomatite	Miask, Russia
Carbonatite	Magmatic	Mountain Pass, USA
	Dykes and veins	Kangankunde Hill, Malawi
	Hydrothermal vein and stock work	Gallinas mountain, Mexico
	Skarn	Saima, China
	Replacement in carbonate rock	Bayan-Ovo, China
	Fenite-metasomatite	Magnet cove, USA
IOGC	Magnetite-apatite replacement	Eagle mountain, USA
	Hematite-magnetite breccia	Olympic Dam, Australia
Pegmatite	Abyssal (HREE, LREE), allanite, monazite, euxenite association	Aldan, Russia; Ytterbi, Sweden; Five mile, Canada
Mo-porphyry	Climax type	Climax, USA
Metamorph	Migmatitized gneiss	Music valley, USA
	Uranium-REE-skarn	Mary Catlin, Australia
Stratiform phosphorite and laterite	Phosphorite in platform setting	South Idaho, USA
	Phosphorits associated with carbonatite	Mount Weld, Western Australia
	Laterite associated with granite	South China
	Baddelite bearing bauxite	Pokos de Kaldas, Brazilia
	Carstic bauxite	Montenegro (Europe)
Paleo placers	Uranium bearing pyrite-quartz pebble conglomerate	Elliot lake, Canada
	Gold bearing pyrite-quartz pebble conglomerate	Witwatersrand, South Africa
Placers	Oceanic paleo placers of titanum	Cooljarloo, Western Australia
	Tin placers	Tin placers in Malaysia

2.1.4. Types of REE ore

Deposits in the differentiated nepheline-syenite massif (Lovozero) are the main ores of niobium, tantalum and REE. The mineralized intrusive has a central-type circular shape and multi-phase zoned structure. Loparite bearing differentiated (phase 2) has rhythmic structure, which consists of layers of nepheline, feldspar and color mineral accumulation, urtite, juvite, foyaite, luyavrite and malinite. Loparite is accumulated as accessor mineral forms thin layers (0.1-2.0 m) at the lower most part together with urtite and malinite. Mineral assemblage consists of nepheline, potassium and sodium feldspar, aegirine, alkaline amphibole, sodalite, zeolite, and as accessore phase forms loparite, willyomite, apatite, eudialite, ramzaite, murmanite, lovoserite, sphene, magnetite, pyrite, and pyrrhotite are formed as accessories. Loparite is the main raw material for the production of niobium, tantalum and cerium group REE.

Carbonatites of ultra-basic, alkaline rock are major source of niobium in the world. Carbonatites of ultra-basic, alkaline rock form rounded and circular shaped bodies, while REE bearing carbonatites are stock, ringshaped dikes and partly tubes.Carbonatite bodies form circular shaped stocks, radial veins, circular and semicircular bodies, and tubular bodies, depending on the type differentiation of ultra-basic alkaline magma.

Carbonatite is composed of calcite, dolomite and ankerite. Pyrochlorine mineralization is appear as dissemination and regularly distributed within the carbonatite body.The ore body has linear shape and with lower content (Nb_2O_5 = 0.05–0.08%), with highly enriched (Nb_2O_5 = 0.2–0.8%) zones.   zone enriched on a base with a poor content.Ore-bearing rocks are dominated by forsterite, phlogopite, and pyrite, together with apatite, monazite, and sometimes zircon, baddeleite, and magnetite as accessory assemblage. If carbonatite consists from medium and coarsesize crystalline calcite, it can be used as carbonate raw material (for example, Beloziminskoe in Russia and St. Honore in Canada).

In rare case, ultra-basic alkaline rock related pyrochlorine mineralization associates with microclinite-potassium feldspar metasomatite (Ikh Tagin deposit, Irkutsk Oblast) instead of carbonatite.In the Ikh Tagin deposit, apatite-pyrochlore mineralization forms zonal structure and it appears as dissemination, vein-dissemination along the 600 m long and 300 m wide mineralized zone. The Nb_2O_5 content this ore reaches up to 1.0%.

In some cases, gatchettolite is enriched partly as small dissemination making independent accumulation within carbonate body, or they also form enrichment along the marginal part of mineralized zone.In tantalum and niobium complex ores the ratio of Nb_2O_5/Ta_2O_5ranges between 4.5–8 (Srednesimin deposit and parts of Belozymine ore zone)

Bastnaesite bearing carbonatite deposits are major source of cerium group REEs. The main representative deposit is Mountain Pass in USA. The deposit consists of a 700 x 200 m stock shaped body and contains 60% of carbonate (calcite), 20% of barite, 10% of quartz and 10% of REE bearing minerals (bastnezite and monazite.The total REE content of the Mountain Pass deposit reachesup to 10% in the rich part and approximately 5% in low grade part. The reserve is estimated that the deposit contains 2.5 million tonnes of ore with cut-off grade 5%(REO total).In case of Mongolia, the Lugiin Gol deposit belongs to this type of carbonatite deposit. It contains 80% of calcite, 10% of dolomite, ankerite and other carbonate minerals and 1%of quartz.The main REE bearing minerals are synchisite, parisite and bastnezite, which makes 10% of the ore and pyrite 1-2% and fluorite 1% are formed asaccessory minerals. More than 400 small veins and dikes of carbonatite, were found in the northern half of the ring-shaped Lugiin gol nepheline syenite massif, and 28 vein bodies have industrial significance were identified.Generally, contet of total REE oxide (TR_2O3) ranges from 1.78% to 28.47% and REE reserve of Lugiin gol deposit is estimated as 806.3 thousand tons of ore with average content of 2.17%

At the weathering surface REE-niobium (Y and Sc) carbonatite deposits occur re-accumulation and enrichmentof mineralization and recently become a promising new type (Tomtor deposit in the Yakut Sakha). Ore body of the Tomtor deposit is large as 2600×1700 m in size and forms layer shaped ore body with thickness up to 10 m.The layered ore body is constsed fromrithmic layers of pyrochlorine-monazite-crandallite rich ore and kaolinite-crandallite poor ore. The main ore minerals are strontium-pyrochlore, barium-pyrochlore, plumbopyrochlore and simple pyrochloride residues which are monazite, pyrochlorinetype minerals. The ore is very rich, containing 4–8% of Nb_2O_5, 6–12% of TR_2O_3, 0.5–0.65% of Y_2O_3, and 0.05% of Sc_2O_3, but they are fine-grained and difficult to processing of ore.Genesis of the deposit is complex and it can be explained in two main ways. The first hypothesis is that the re-accumulation of the weathering surface of the REE-bearing carbonatite body contained in the ultra-basic-alkaline rock. It is supposed to be sedimentary-placer type formed in a small lake environment. The second hypothesis is explained by epigenetic process: due to the significant transport of iron and manganese on the weathering crust caused enrichment of niobium and REE minerals in the residual crust. Although there are two possible geneticprognoses, it is likely that both processes might be co-evolved

The Bayan Obo deposit, the world's largest producer, contains niobium-REE-iron ore, which is considered to be of overlapping origin. Niobium and REE mineralization is contained in about 3 km wide and about 16 km longmineralized zone.Rare metal and REE mineralization is found in metamorphosed iron ore in late Proterozoic-Early Paleozoic age dolomite. Gabbro, alkaline intrusive, and granite rocks are distributed throughout the deposit, and REE-enriched(TR_2O_3: 2–3.5 %) carbonatite dikes and veins. The main ore minerals are magnetite and hematite, and the fine-grained impregnations of monazite, bastnaesite, pyrochlore, and eshinite. Iron content reaches up to 45% and higher in the rich ore, REE content ranges 5.7-6.7% (TR_2O_3), and niobium is 0.126–0.14% (Nb_2O_5).Reserve estimation of Bayan-Obo deposit is as following: 470 million tons of iron, 40.1 million tons of TR_2O^3 and 1 million tons of Nb_2O_5. Ore genesis is very complicated, researchers hypotised that REE and niobium mineralization is associated with carbonatite magmatism wich is developed overlapping sedimentary-metamorph iron ore.

The main representative of yttrium-groupHREE mineralization is Ion-adsorption type ore, which are found in southern China and are associated with the weathering surface of granite, shale, and amphibolite.

In addition to the above mentioned main types of REE mineralization, following ore types have been used in the Russia. These include:

- Zirconium-niobium mineralization contained in albitite and carbonatite related nepheline syenite bodies and pegmatite (Vishnevogorsk deposit, Russia, Urals)
- Yttrium groupREEmineralization contained in quartz-chlorite metasomatite (Kutessai-II deposit, Kyrgyzstan)
- Organic sedimentary scandium-REE-uranium deposit (Melovoe deposit of Kazakhstan).

Most of these deposits have been mined out and closed.

In case of Mongolia 5 REE deposits are found and explored:

- Khalzan burgedei: Alkaline metasomatite related REE-Zr-Hf-Ta-Nb deposit
- Mushgai khudag: Carbonatite type deposit. Apatite dominated LREE mineralization is formed. It is enriched by magnetite, fluorite and monazite in certain places of the deposit
- Khotgor: Similar to Mushgai khudag deposit by geological setting and mineralization characteristics. Main ore mineral is britholite
- Lugiin gol: Carbonatite type deposit, which is dominated by bastnaesite-synchisite-parisite.
- Ulaan del: Alkaline metasomatite related REE-Zr-Hf-Ta-Nb mineralization.

Table 5. Industrial types of REE deposits

Industrial type of deposits	**Morphological type of ore body**	**Ore type (mineral)**	**Content of main resource, %**	**By product resources**	**Industrial type of ore (technological type)**	**Sample deposit**
1	2	3	4	5	6	7
Cerium group HREE , niobium and tantalum deposit contained in differentiated nepheline-syenite body	Inclined layer shaped bodies contained within urtite, juvite and malinite	Loparite	Nb_2O_5: 0.2-0.40; Ta_2O_5: 0.018-0.027; TR_2O_3: 0.9-1.4	Ti, Sr, Th	REE-tantalum-niobium (sorting, gravitation-floatation-hydrometallurgy)	Lovozero (Russia)
Carbonatite hosted niobium, associated with and contained within ultrabasic and ultra alkaline rock	Lens shaped veins and stock and tube shaped bodies within carbonatite body	Pyrochlore	Nb_2O_5: 0.2–0.8	P, REE, Ta, U, Zr	Metallurgical niobium (sorting, gravitation-floatation-hydrometallurgy)	Beloziminsk (Russia), St.Honore (Canada)
	Lens shaped body contained in microclinite	Pyrochlore	Nb_2O_5: 0.3–1.2	P, microcline	Metallurgical niobium (sorting, gravitation-floatation-hydrometallurgy)	Ikh Taginsk (Russia)
Cerium group REE contained in bastnaesite bearing carbonatite	Stock, vein and tube shaped bodies contained in carbonatite	Bastnaesite	TR_2O_3: 0.9–9.0	Fe, U, Th, barite, fluorite	Fluorite-barite-strontium-REE (sorting, gravitation-magnetic separation-floatation-hydrometallurgy)	Karasug (Russia), Mountain Pass, Lugiin gol, Mushgai khudag, Khotgor
Niobium-tantalum deposits contained in alkaline metasomatite	Stock and lens shaped bodies within quartz-albite-microcline and albite metasomatite of alkaline granite	Zirkon-pyrochlore-columbite	Nb_2O_5:0.12-0.40;Ta_2O_5:0.014-0.040; ZrO_2: 0.3–0.7	REE, Li, Th, U, Hf, Rb, cryolite	Metallurgical zircon-niobium-tantalum (sorting, gravitation-floatation-hydrometallurgy)	Ulug-Tanzek8 Zashichinsk (Russia)
REE-niobium-tantalum deposit contained in alkaline metasomatite	Lens and layer shaped bodies in alkaline metasomatite	Zirkon-tantalum-pyrochlore and REE	Nb_2O_5: 0.20–0.40; Ta_2O_5: 0.012-0.025; ZrO_2: 1.5–1.6 TR_2O_3:0.2–0.4	Y, U, Th, Hf, Zn, Pb,cryolite	Zircon and REE bearing metallurgical niobium-tantalum (gravitation-floatation-hydrometallurgy)	Katuginsk (Russia), Khalzan burgedei, Ulaan del

2.2. Niobium and tantalum

2.2.1. General introduction of niobium and tantalum, use and importance

Niobium and tantalum are very similar in chemical properties and are always formed together in nature.

Niobium is the 41^{st} element of Mendeleev's periodic table. Metallic niobium has a steel-like gray color with a specific gravity of 8.57 gr/cm^3, it melts at 2415°C and boils at 3300°C. Niobium has an atomic weight of 92,906 and a stable isotope of ^{93}Nb in nature. Vinogradov estimates that niobium clark in the Earth's crust is 0.002%, 0.0001% in ultra-basic rocks, 0.002% in basic rocks, 0.002% intermediate rocks, 0.002% in felsic rocks and 0.01% in alkaline rocks

Tantalum is the 73^{rd} element in the Mendeleev periodic table and has an atomic weight of 180.95. It has two stable isotopes in nature, ^{180}Ta and ^{181}Ta, oxidizes by +5 degrees, and is geochemically similar to niobium. A.P. Vinogradov estimates that tantalum clark in the Earth's crust is 0.00025%, 0.0000018% in ultra-basic rocks, 0.000048% in basic rocks, 0.00007% intermediate rocks, 0.00035% in felsic rocks and 0.0008% in alkaline rocks. Nb/Ta ratio is 1:55 for ultra-basic rock, 1:41 for basic rocks, 1:26 for intermediate rocks and 1:6 for felsic rocks. The specific gravity of tantalum is 16.6 gr/cm^3, it melts at 2996°C and boils at 5300°C. It has silvery light gray color. It is one of the most heat-resistant metals, after tungsten and rhenium.

Niobium is widely used in the metallurgical industry as a ferroniobium (up to 65% Nb) in stainless steel and as an additive in the production of high quality alloys. Such alloys are resistant to acidic and alkaline environments.Niobium alloys are strong, heat-resistant, and non-corrosive, so they are used in many industries, including oil and gas pipelines (large sizes), nuclear boilers, rockets, aerospace, chemical industry equipment, high-pressure boilers, and railroad tracks. Used in small chemical and electrical engineering industries. Niobium alloys combined with Ni, Sn, Zr, Ti, and Ge, increase electrical conductivity at relatively high temperatures (23K). Alloys made from Nb-Zr, Nb-Ti, and Nb-Sn have very high capacity of electric conducticity, therefore it is used high-strength magnets. When turbine generators use coils made from Nb-Ti alloy, it reduces weight 4-5 times and efficiency increases up to 99.5-99.8%.Some alloys mixed with nickel, cobalt, and iron are used jet engines, missiles, gas turbines, and thermal insulation. Niobium has recently been used as a catalyst for the production of bio-fuels (diesel) from palm oil. 87% of niobium production is used in steel production, 5.2% in chemical industry, 2.7% in vacuum furnace production, 2.5% in niobium alloys, and 0.9% in metal niobium production

The main industries that use tantalum are the technical field of electric vacuum (anodes, grids, receivers, high temperature vacuum furnace equipment), as well as the production of heat-resistant hard alloys used in cutting tools, various chemical tools, laboratory equipment, alloys and steel quality improvement. In addition, tantalum is the only metal that is best suited for implantation in the human body, so it is used in medicine, surgery, vascular suturing, various prostheses and other necessary tools.

Almost half of the tantalum production is used in powder and wire in the electrical industry. Tantalum's unique ability to accumulate energy losses is used in the manufacture of electrical capacitors, telecommunications (mobile phones), large data storage devices (hard disks) in the medical sciences (hearing aids, heart machines). Tantalum carbide is also used in cutting tools to improve the refractive index of tantalum oxide amplifier glass.24% of tantalum production is used in powder form for condenser production, 22% in crusher production, 18% in chemical production, 17% in metallurgy, 12% in tantalum ingots and 7% in tantalum carbide production.

Both niobium and tantalum are found in many minerals. There are 83 minerals that contain niobium, 60 of them are oxides and 22 are silicates, and one is pure metal.Main producing minerals of niobium are pyrochlorine, gatchettolite, columbite, and in a lesser extent it is produced from loparite, tantalite and tin slag. Nb_2O_5 content of carbonatite ore is 0.5–2% and in weathering deposit it is0.1–1.5%.

There are 37 minerals that contain tantalum, all of which are oxide minerals. The main minerals are tantalite, wodginite, tapiolite, microlite, columbite, loparite, gatchettolite and samarskite. Information on the main minerals of niobium and tantalum ores is shown in Table 6.

Table 6. Ore minerals of nibium and tantalum

Name of minerals	Chemical formula	Content of oxide, %		Trace elements	Dencitygr/cm^3
		Nb_2O_5	Ta_2O_5		
Columbite	$(Fe, Mn)(Nb, Ta)_2O_6$	59–78.7;	1–20	–	5.3
Tantalite	$(Fe, Mn)(Ta, Nb)_2O_6$	0.2–20	63–86	–	8.3
Pyrochlore	$(Na, Ca)_{2-x}Nb_2O_6(OH, F)$	52–71;	до 7.0	U, Th, TR	3.8–4.7
Microlite	$(Ca, Na)_2Ta_2O_6$ (O, OH, F)	0.9–10	55–80	U	5.9–6.4
Tapiolite	$Fe(Ta, Nb)_2O_6$	9–22	62–85	–	6.4–7.9
Ixiolite	$(Ta,Nb,Sn,Mn,Fe)_4O_8$	8.3	68.96	Mn, Sn	7.23
Wodginite	$(Ta, Nb, Mn, Sn, Fe)_2O_4$	0.1–15	65–75	Sn	7.19–7.36
Loparite	$(Na, Ce, Ca)(Ti, Nb, Ta)O_3$	8.0–12.8;	0.6–0.8	Ti, TR, Sr	4.6–4.9
Lueshite	$NaNbO_3$	81.09		-	4.44
Euxenite	$Y(Nb,Ti,Ta)_2(O,OH)_6$	47.43	22.53	Y, Ce,	4.84
Struverite	$(Ti, Ta, Nb, Fe)O_2$	11.32	37.65	Ti	4.25
Gatchettolite	$(Ca, U, TR)_{2-x}(Nb, Ta)_2O_6(F, OH)_{1-x} \cdot 2H_2O$	35	18	Th, TR	4.4–4.9
Marinyakit	$(TR, Na, Ca)_{2-x}(Nb, Ta)_2O_6 \cdot \cdot (OH, F)$	50	5	REE, U	4.13–4.15
Ilmeno-rutile	$(Ti,Nb,Fe^{3+})O_2$	27.9	-	Ti	4.6

2.2.2. Genesis of Niobium and Tantalum deposits

Endogenous tantalum deposits are formed along with niobium in pegmatitesand tantalum bearing feldspar metasomatites of felsic and alkaline rock, which account 42.5% of the world's tantalum endogenous deposits reserve. Alkaline granite and agpaitic nepheline syenites account for 57.5% of its endogenous reserves. Carbonatite deposits contain 6% of the endogenous tantalumreserves. Deposits associated with felsic and alkaline granites are formed during the activation phase of the ancient platform and folded regions, the continental rift zone, and the late orogenic stage. In terms of mineralization epoh, it is formed in the pre-Cambrian, Caledonian, Hercynian and Cimmerian periods. Hercynian epoh is the most significant, accounting 36% of all tantalum reserves, 41% pre-Cambrian deposits, 15% Caledonian, and 8% Cimmerian and Alpine epoh. Weathering and placer deposits are formed under the platform conditions.

Endogenous niobium deposits are located in continental rift zones formed by ancient platforms, folded structures, and post-collision uplifting related granites. It is formed in several stages of metallogeny, but the intensity of mineralization increases from the Archaean to the Cimmerian. 68.8% of the total niobium reserves were formed during the Cimmerian period, 24.1% during the Hercynian period, 2.6% during the Caledonian period, and 3.5% during the Pre-Cambrian period. Under platform conditions, weathering and placer deposits of small amounts of carbonatite and alkaline pegmatite have formed in the folded regions.

Niobium and tantalum deposits are often formed in direct relation with rocks of deep origin, such as granite, syenite, and carbonatite. Weathering of these deposits has resulted in the accumulation of weathering surface dust in some areas, resulting in the formation of secondary deposits. The main types of niobium and tantalum deposits are shown in Table 7.

Table 7. Genetic types of Niobium and Tantalum deposits

Deposit type	**Brief introduction**	**Ore content and reserve**	**Main example**
Carbonatite related	Nb>Ta. Perovskite and pyrocholre type mineralization within carbonatite intrusive	Big variety in size. Biggest deposit has 2900 mln.tn pre with 2.85% Nb_2O_5. Whereas at Niobek Oka deposit has 46 mln.tn ore with 0.53 % Nb_2O_5	Morro Dos Seis Lagos, Brazilia, Niobek Oka, Canada
Alkaline granite and syenite related	Nb>Ta. It is formed in close relation with alkaline and felsic granitoid. Mainly niobium dominated tantalum poor deposits formed	Mainly 1000 mln.tn and lesser ore with 0.1-1.0 % Nb_2O_5, Ta_2O_5 content is 0.05 %.	Motzfeldt, Greenland, Lovozero, Russia, Tore lake and Strange lake, Canada
Rare metal granite related	Ta>Nb. Formed at the late stage of magma crystallization along the apical part of peraluminous granitoid. Looks like magmatic-hydrothermal	Mainly 100 mln.tn and lesser ore with 0.05 % Ta_2O_5 content	Yichun, China Nuweiba, Egypt Abu Dabbab, Egypt
Li-Cs-Ta type pegmatite	Ta>Nb. Formed in Li-Cs-Ta-enriched pegmatite.	Mainly 100 mln.tn and lesser ore with 0.05 % Ta_2O_5 content	Green Bush and Wodgina, Australia, Volta Grande, Brazil
Weathering crust related, secondary	Niobium and tantalum ore minerals separated from ore in the weathering environment and forms placer deposit	Mainly 1000 mln.tn and lesser ore with 3% Nb_2O_5. In Tomtor deposit it reaches up to 12%.	Tomtor, Russia Araxa, Brazil Green Bush, Australia

2.2.3. Types of Nb, Ta ore deposit

Niobium-tantalum deposits in alkaline granite metasomatite are contained in small (1-1.5 km^2) ribekite and aegirin-ribekite bearing bodies. The main reserves of niobium-tantalum ore are formed in quartz-albite-microcline metasomatite (Ulug Tanzek) and are usually stable continue in the vertical direction. The rich part of the ore forms an albite metasomatite (albite) near the inner boundary of the massif (Zashikhinsk). The main ore minerals are columbite, pyrochlore and zirconium, which form fine-grained impregnations with irregular distribution.

REE-niobium-tantalum deposits (Katuginsk deposit, Chita oblast), contained in the alkaline metasomatite distributed along the regional fault zone, looks like no source of magma, they only tend to be distributed along the large fault zone and associated with amphibolite phase metamorph zone. Metasomatites containing mineralized quartz-albite-microcline (arfvedsonite, biotite, etc.) form stratified lens shaped bodies. The main ore minerals are tantalum-containing pyrochlore, zirconum, gagarinite and REE-bearing fluorite.

Tantalum deposits in lithium-fluorine granite occur in fine to medium grained amazonite granite bodies(0.5–1.5 km^2) containing albite, topaz, and lithium mica. Tantalum mineralization forms at the apical part of the intrusive body and the Ta_2O_5 content is 0.01-0.04%. The mineralization is small in the vertical direction and does not exceed a few tens of meters. The ore body is inclined and ore minerals are impregnated and vein-impregnated type. The main ore minerals are tantalite-columbite and microlite (Orlovsk and Etykinsk deposits in Chita region).

The lithium-tantalum deposit in spodumene granite was first discovered in 1989 (Alakhinsk deposit in the Altai Mountains) and it is new type of production. Rare metal mineralization forms a dome-shaped body at the apical part of a small spodumen-bearing granite body (~0.4 km^2). Tantalum mineralization is associated with spodumene and ore mionerals are fine-grained tantalite and microlite. The average Ta_2O_5 content of the ore is 0.012%, while the Li_2O content is 0.71%. In the deeper part, content lithium-tantalum ore become poorer (Li_2O content 0.3-0.4%) and gradually shifts to spodumene lithium ore.

Tantalum deposits (Li, Cs, Be) in pegmatite are the main source of tantalum production. Pegmatite deposits have been identified in Russia and many other countries. The largest and richest deposits are formed on an ancient platform. Pollucite-spodumene-tantalite bearing pegmatites are the most widespread, and the weathering surface formed by them is the main source of tantalum production in the world. The Ta_2O_5 content reaches up to 0.02–0.03%, sometimes 0.1%, and the Nb/Ta ratio averages 1–3 (up to 6). The main ore minerals are tantalite, tantalite-columbite, microlite, spodumene, pollucite and beryll. In some deposits, lithium has increased in deeper part, while content of tantalum, rubidium, and cesium decreased, making vertical zonation.When estimating ore reserve of pegmatite related mineralization the boundary is usually taken by boundary pegmatite body.

Niobium, tantalum andREE mineralizations formed in weathered surface are caused by surfacial geological processes occurred on the surface of REE-bearing rocks and deposits. They are divided into two main types: residues and infiltration. Weathering surface related deposits are formed from following types of rock: 1) carbonatites related with ultra-basic, alkaline rock; 2) carbonatite and alkaline metasomatite in the zone of regional fault; 3) weathering of primary deposits such as pegmatite.

Niobium and niobium-REE deposits that formed on the weathering surfaces of ultra-basic, alkaline rock carbonatites form large layered and lens shaped bodies. Depending on intensity and type of the weathering process, ore minerals show wide difference. Columbite and pyrochlore (Beloziminsk deposit) are formed on the weathering surface with hydrousmica, while secondary pyrochlore (strontium-pyrochlore, barite-pyrochlore) and REE-containing phosphate (monazite, sometimes florensite) (Chuktukonsk deposit in Russia) minerals are formed on the surface of the laterite. The weathering surface of the laterite is relatively high in niobium (up to 3% Nb_2O_5) and accounts for the majority of the world's niobium reserves.

Niobium deposits on the weathering surface of carbonatite and alkaline metasomatite in the regional fracture zone are associated with lens and vein shaped carbonatite body, and here the niobium content is poor. The ore body follows the shape of the original body and the grade increases 2-4 times. The ore body is lenticular shaped and elongated (up to 100 m thick and up to 2000 m long). The ore minerals are pyrochlore, columbite and apatite. The ore contains 0.4–0.75% Nb_2O_5, reserve of deposit is small.

In the case of tantalum deposits formed on the weathering surface of pegmatite, the ore body has lens and layered shape, and the main ore minerals are tantalite, columbite-tantalite, beryll and cassiterite. Ta_2O_5 content ranges 0.004–0.03% (up to 0.1%).

Table 8. Ore types of Niobium and Tantalum deposit

Industrial type of deposits	**Morphological type of ore body**	**Ore type (mineral)**	**Content of main resource, %**	**By product resources**	**Industrial type of ore (technological type)**	**Sample deposit**
1	2	3	4	5	6	7
REE-Niobium-Tantalum deposits contained in alkaline metasomatite	Lens and Layer shaped bodies in alkaline metasomatite	Zircon-tantalum-pyrochlore and REE	Nb_2O_5: 0.20-0.40; Ta_2O_5:0.012-0.025; ZrO_2:1.5-1.6; TR_2O_3:0.2-0.4	Y, U, Th, Hf, Zn, Pb, cryolite	Zircon and REE bearing metallurgical niobium and tantalum (gravitation-floatation-hydrometallurgy)	Katuginsk (Russia)
Lithium-Fluorine granite hosted tantalum deposit	Lens or dome shaped bodies at the apical part of amazonite granite	Microlite-tantalite-columbite	Ta_2O_5:0.010-0.018	Nb, Li, Sn, Rb, amazonite	Chemical-metallurgical tantalum(gravitation-floatation-hydrometallurgy)	Orlovsk Etykinsk (Russia)
Lithium-tantalum deposit hosted by spodumene granite	Dome shaped bodies at the apical part of spodumene bearing granite	Spodumene-tantalite	Ta_2O_5: 0.010-0.016 Li_2O: 0.6-1.0	Nb, Rb, Cs	Chemical-metallurgical niobium bearing lithium-tantalum (gravitation-floatation-hydrometallurgy)	Alakhinsk (Russia)
Tantalum (Li, Cs, Be) deposit hosted by pegmatite	Tabular and vein shaped bodies hosted by amphibolites gneiss and schist	Spodumene-beryll-tantalite, Pollucite-spodumene-tantalite, Lepidolite-microlite	Ta_2O_5:0.01-0.03;Cs_2O: 0.1-0.8; Li_2O: 0.3-1.5; BeO: 0.02-0.07	Sn, Rb, Nb, Ga	Chemical-metallurgical beryll-lithium-cesium-tantalum (sorting, gravitation-magnetic separation-floatation-hydrometallurgy)	Zavitinsk, Wishnevskoe (Russian), Bernik Lay (Canada), Green Bush (Australia)
Niobium and REE-niobium deposits hosted by weathering crust of ultrabasic, alkaline rock and carbonatite	Layer and lens shaped bodies formed in the weathering crust of ultrabasic, alkaline rock and carbonatite	Apatite-pyrochlore-columbite	Nb_2O_5: 0.4-1.0; P_2O_5: 10-16	TR, Ta, Fe	Metallurgical niobium (sorting, gravitation-floatation-hydrometallurgy)	Beloziminsk (Russia)
		Sr-, Ba-пиро-хлор	Nb_2O_5 1.0-3.0	TR, Fe, P, Mn		Arasha (Brazil)

Industrial type of deposits	Morphological type of ore body	Ore type (mineral)	Content of main resource, %	By product resources	Industrial type of ore (technological type)	Sample deposit
1	2	3	4	5	6	7
Niobium deposits hosted by weathering crust of carbonatite and alkaline metasomatite in regional fault zone.	Lenticular shaped bodies in the weathering crust of carbonatite and alkaline metasomatite	Pyrochlore, columbite-pyrochlore	$Nb_2O_5$0.4-0.8	P, Fe, vermiculate	Metallurgical niobium (sorting, gravitation-floatation-hydrometallurgy)	Tatarsk (Russian)
Tantalum (Sn, Be) deposits hosted by weathering crust of pegmatite	Layer and lens shaped bodies in the weathering crust of pegmatite	Beryll-columbite-tantalite	Ta_2O_5 0.004-0.03	Sn, Be, Nb	Chemical-Metallurgical beryl-tantaum (gravitation-floatation-hydrometallurgy)	Nazarenu (Brazil), Green Bush (Australia)
Scandium-REE-niobium deposit hosted by weathering crust of carbonatite	Layer shaped bodies in the weathering crust of carbonatite	Monazite-Sr-, Ba-, Pb-pyrochlore	Nb_2O_5 4-8; TR_2O_3 6-12; Y_2O_3 0.5-0.65; Sc_2O_3 0.05	P_2O_5	Chemical-Metallurgical REE-niobium (sorting, gravitation-floatation-hydrometallurgy)	Tomtorsk (Russian)

Three. Grouping deposits by geological complexity in order with exploration purposes

Based on the shape and size of the ore body, changes in its thickness and internal structure, and the distribution characteristics of niobium, tantalum, and REE oxide content in the ore, deposits are classified into four (group I, group II, group III, group IV) groups, following the instruction "Mineral Resources and Deposit Classification and Guidelines" approved in 2015.

Group I deposits includethe deposits which has simple geological setting and belongs following ore bodies or parts of deposit

- Deposits with large in size and reserve with regular distributed mineralization, elongated (nx1000 m), stable stratified or layered ore bodies containing loparite. (Lovozero deposit in Russia)
- Large stock shaped ore bodies (1.8-0.8 km) hosted by alkaline granite with regularly distributed mineralization is evenly distributed (Ulug-Tanzek deposit).
- Clay deposits contained uranium, REE, strontium, apatitized fish teeth and bones with a high content of scandium, layer-type body with very stable thickness and elongation (Melovoe deposit)

Group II deposits includethe deposits that having complicated geological setting and bigger sized ore bodies and part of deposit as following:

- Carbonatite type large bodies (Belozumin deposit, Russia) lenticular and arched bodies with stable continuation along the length (nx100 m in length)
- weathering of carbonatite surface and (Belozumin and Tomtor deposits in Russia)
- Large layer shaped (n x 100 ~ n x 1000) x n·100 m) bodies that formed and re-accumalted in the weathering crust carbonatite
- Large lens-shaped ore bodies hosted by rare metal granite and apogneiss metasomatite (Orlovsk, Etykinsk, Katuginsk deposits of Russia)
- Pegmatite type tabular shaped elongated deposits (1–2 km)

Group III deposits include the deposits that having quitecomplicated geological setting as follow:

- Large and medium sized veins and cluster veins of pegmatite with quiate complicated geological setting (Belorechensk, Goltsovoe, Vishnyakovsk deposits)
- Lenticular and lens shaped ore bodies formed in the weathering crust (Tatarsk deposit)
- Vein and tube shaped ore bodies with very irregular distribution of niobium, tantalum, andREE mineralization.

Group IV depositsincludes the deposits that include small veins, lenses, interrupted nest like smallbodies with very irregular distribution of minerals, which are economically irrelevant in independent case

Belonging of certain deposit (area) to a particular group is determined by the degree of complexity of the geological structure of the main ore bodies, in which the predominant part of the reserves of the field (at least 70 %).

REE, niobium and tantalum deposits can be classified as large, medium and small in terms of reserve size and can be also subdivided as rich, medium and poor in terms of major mineral content (Table 9).

Table 9. Classification of deposits by its reserve and content

CLASSIFICATION OF DEPOSITS BY RESERVE				
№	**Type of mineralization**	**Large**	**Medium**	**Small**
1	REE (TR_2O_5), thousand tn Cerium group LREE Yttrium group HREE	 >10,000 >100,000	 1,000 10,000	 <1,000 <10,000
2	Niobium (Nb_2O_5), thousand tn	>300	50-300	<50
3	Tantalum (Ta_2O_5), thousand tn Primary Placer	 >5 >1	 0,5-5 0,1-1	 <0,5 <0,1
CLASSIFICATION OF DEPOSITS BY CONTENT				
1	REE (TR_2O_5), %: Cerium group LREE Yttrium group HREE	 0.3-1 0.03-0.1	 1-5 0.1-0.5	 >5 >0.5
2	Niobium (Nb_2O_5), %	0.03-0.15	0.15-1	>1
3	Tantalum (Ta_2O_5), %	0.005-0.01	0.01-0.25	>0.25

Four. Study geological setting, ore mineralogy and ore types

4.1. For the explored deposit, it is necessary to have a topographic map, the scale of which would correspond to its size, the peculiarities of the geological setting and local landscape-geomorphological conditions.Topographic maps and plans for primary REE deposits are usually drawn up at a scale of 1:1000 to 1:5000. 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. Underground mine workings and boreholes are plotted to the plans according to the engineering survey (markscheider work). Surveying plans of mining horizons are usually drawn at scale 1:200, consolidated (unified) plans at scale 1:1 000 and larger. 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.

4.2. The geological settings of the deposit should be studied in detail and plotted on the geological map at scale 1:1000 to 1:10000 depending on the size and complexity of the deposit, and on geological sections, plans, projection planes, and, if necessary on the block diagrams and 3D models. Geological and geophysical data on certain deposit should determine the size and shape of ore bodies, the conditions of their locations, the internal structure and continuity (degree of enrichment of ore for mineralized zones), the nature of the pinching out of ore bodies, mineral distribution in it, the placement of different types of ores, features of changes in the host rocks and the relationship of ore bodies with host rocks, folded structures and tectonic faults, and their relationship to the host rocks, and sufficient to justify the calculation of reserves. Also, it is necessary to justify the geological boundaries of the deposit and the prospecting criteria that determine the location of prospective areas within assessed resources must evaluated by P_1 grade.

4.3. Outcrops and surface of ore bodies or mineralized zones of REE are studied with trenches, pits, and pits with shafts (it intersects the ore body by horizontal excavation from lower part), tranchee ore tunnel (it digs the ore body along the strike and reveals the ore body) and shallow boreholes. In addition, geophysical and geochemical methods allow determining the condition of location, forms and size of ore-bodies, and structure, thickness and locating depth of oxidation zone, the degree of ore oxidation, detailed determination of mineral composition and technological properties of primary, mixed and oxidized ores; and reserve estimation of ores has to be completed separately for industrial (technological) types.

4.4. Deep exploration of REE deposits is carried out mainly by boreholes with a combination of excavation works (underground excavation works are used for deposits with very complex geological structure) as well as geophysical surveys of surface, excavation, boreholes and underground mining. Methods of exploration – types and volumes of geophysical studies, their purpose and coordination with drilling procedures, the need for excavation, geometry and density of the exploration grid, sampling method and methodic have to correspond the deposit to the complexity group of geological structure, and they provide ability to reserve estimation in proper reserve classifications. Exploration methodology is determined based on features of deposit's geological setting, exploitability of excavation, drilling and geophysical equipment selected for exploration and experience of exploration and mining of similar deposits.

When choosing the optimal exploration methodics the following issues should be considered, degree of variety of Nb_2O_5, Ta_2O_5, TR_2O_3content, its spatial distribution patternof REE, niobium and tantalum bearing ore minerals, features of structure and texture (whether there is a large separation of ore minerals), erosion condition of core during the drilling depending on geology environment, as well as character of crumpling, splitting and adhesive ore and barren minerals during sampling at excavations. It is also important to analyze and compare duration for conducting the various possible exploration worksas well as technical and economic indicators.The depth of exploration is limited by the degree to which it is economically viable to exploit the deposit using modern technology.

4.5. From core drill holes 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.

From the practice of geological exploration works, the core recovery has to be not less than 90% for each run during the drilling.The accuracy of the determination of the linear core recovery shall be systematically monitored by weight or volumetric method and must be documented.

The representativeness of the core that obtained to determine quality Nb_2O_5, Ta_2O_5, TR_2O_3 content and thickness of ore-intervals must be confirmed by studies of the possibility of its selective abrasion. The degree of selective abrasion is studied in relation to variegated core recovery and ore types. For this purpose, it is necessary to use data from the study of physical and mechanical properties of ores, data of samples obtained from excavation works and drill holes, down hole logging results, materials of exploiting exploration and mining operations, as well as the results of statistical processing of data on intervals with different core recoveries.If the results of the sampling are slightly deviated due to lower core recovery or selective abrasion, a correction coefficient for using the results of core sampling, should be determined based on results of controlling excavations and boreholes.

In the case of ore intersected core recovery is 95% or lower, it is necessary to use methods of geophysical studies in boreholes toincrease the reliability and informativeness of drilling. The rational combination of geophysical survey is defined depending on work aim, geology-geophysical special features of deposit and modern possibilities of geophysical methods. Re-drilling is required when the core recovery is not sufficient and complex geophysical downhole surveys should be used as it helps to differentiate ore intersection and define its parameters.

In vertical boreholes with a depth of more than 100 m and in all inclined boreholes every 20 m, intervals have to be controlled measurements registering azimuthal and zenithal angles. The results of the measurements must be used for compiling geological cross-sections and horizontal plan maps and for estimation of thickness of ore intervals.In the presence of intersections of boreholes by underground mine workings, the exact coordinates on the intersections have to be submitted by the data of underground survey tying. For boreholes, it is necessary to ensure that they cross the ore bodies at an angle of not less than 30°. For crossing steep or vertical ore bodies at large angle it is advisable to conduct inclined drilling procedures. To improve the efficiency of exploration, it shall be carried out drilling multi-hole boreholes, and in the presence of undergroundmining horizons – underground drill holes. Drilling in the ore, it is advisable to produce a single diameter.

4.6. The excavations are the main ways to study in detail the internal structure, shape, occurring condition and chemical composition of ore bodies and continuation condition, to control information of drilling and geophysical surveys as well as to take technological sample. It is required to define the most significant value of the ore sections that meet the conditional requirement for evaluating the possibilities of selective mining. The continuity of ore body, its thickness along the strike and dip and varieties of REE content are required to be studied on parts that able to represent. Vein type deposit with a small thickness is investigated by underground horizontal excavation (continuous drift) that excavates along the ore body and rise working which traces along the dipping direction of ore body. However, mineralized zone and stockwork type ore bodies with a large thickness are studied by dense grids of ort, crosscut /querschlag and horizontal underground boreholes. Exploration excavations are also aimed to clarify the geological settings and whether to use the results of geophysical survey and assay results of core samples for reserve estimation as well as to define the core decreases due to selective abrasion during the drilling. The exploration excavation should be carried out at parts require detailed study and planned levels for mining at first.

4.7. The location of exploration workings and the distance between them should be determined for each structural and morphological type of ore bodies. In this case, it should be considered that the pillar-like distribution might be occurred in the enriched parts. The summarized information on the density of exploration grid that used in the exploration of primary REE and rare metal deposits in the Former USSR, Commonwealth of Independent States (CIS) countries and Mongolia, is shown on Table #10 and it can be taken into account in the design of geology-exploration.For certain deposit, the most rational exploration method and exploration grid density are justified on the basis of studying data of the deposit or available geological and geophysical data or results of detailed and careful analysis of all and operational materials of similar deposits.

4.8. To confirm the reliability of reserves, some individual areas and horizons of the deposit should be explored in the most detailed way. These areas should be studied and sampled with denser exploration grid than the rest of the deposit. Reserves in some areas and horizons of the GROUP I and GROUP II deposits shall be estimated mainly in PROVEN+MEASURED (A+B) and MEASURED (B) classifications. In case of GROUP III deposits mainly in INDICATED (C) classification. In this case, at least two times smaller the size of the exploration grid used to estimate the potential "C" grade reserves should be compacted in the detailed study of GROUP III deposits

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 formula using geostatistical modeling methods like as inverse distance weighting, Kriging and others. Areas that are under detail shall include major part of deposit reserve and prevailing part of quality of mineral resource, reflecting placement condition and shape of mineral resource and locating within frame of reserves that are subject to priority development of mining. As far as possible, such parts should be within the boundaries of the extractive reserves first. In cases where the areas designated for priority development are not typical for the entire deposit in terms of geological setting feature, ore quality and mining and geological conditions; the areas that meet these requirements shall also be studied in detail.

Resource estimation of deposit with interrupted mineralization should be done using mineralization coefficient within united contour without doing geometrization for the ore body. But for the parts containing economic profitable ores, the possibility for selective mining has to be evaluated based on determination of its spatial distribution, real shape and size.

Geological information collected from the areas where investigated in detail is used for determining the complexity group of deposits. In addition, selected exploration equipment, methodology, exploration grid and its shape are used to verification whether these methods are adequate with features of geological settings of the deposit, to access the confidence of parameters used for reserve estimation in other part of the deposit and to evaluated the condition to mine the deposit wholly. But for the exploitative deposits, the results of exploration during mining and exploitation are used for above mentioned purposes.

Table 10. Summarized information on the density of exploration gridused for explorationREE, niobium and tantalum deposits

Deposit group	Type of ore bodies	Excavation types	Distance between the points of ore body intersected by excavations, corresponding to reserve classification, m					
			A		B		C	
			along strike	along dipping	along strike	along dipping	along strike	along dipping
1	2	3	4	5	6	7	8	9
GROUP I	Large deposits with regular distribution minerals and elongated stable stratified or layered	Bore holes	250	100	500	200	1000	400
	Large stock shaped ore bodies hosted by alkaline granite with regularly distributed mineralization	Bore holes	100	50	200	100	200	200
GROUP II	Carbonatite type lenticular and arched shaped large bodies; Large lens-shaped ore bodies hosted by rare metal granite and apogneiss metasomatite, with irregular distribution of Nb_2O_5, Ta_2O_5, TR_2O_3;Large layer shaped bodies that formed and re-accumalted in the weathering crust carbonatite	Bore holes	–	–	50–100	50–100	100–200	100–200
	Pegmatite type tabular shaped elongated deposits, with complicated structure and irregular distribution of Ta_2O_5	Underground excavation (horizontal and, drift)	–	–	Conti nuous	40–60	–	–
		Ort	–	–	40–60	–	–	–
		Vertical shaft	–	–	80–120	Conti nuous	–	–
		Bore hole	–	–	100	50	100–200	50–100
GROUP III	Medium sized pegmatite type vein and cluster veins; Lenticular shaped body formed on weathering crust of carbonatite	Undergraound excavation (horizontal, drift)	–	–	–	–	Conti nuous	20–30
	Lens shaped ore bodies formed on weathering crust of carbonatite	Орт,	–	–	–	–	20–40	–
		Vertical shaft	–	–	–	–	60–80	Continu ous
		Bore hole	–	–	–	–	50–100	10–50
GROUP IV*	Very irregular distribution of Ta_2O_5 and un stable thickness small vein cluster vein, tube shaped ore bodies of tantalum ore	Drift	-	-	-	-	Conti nuous	20-30
		Ort	-	-	-	-	20	-
		Vertical shaft	-	-	-	-	At least 1 excavation for each body	
		Bore hole	-	-	-	-	25	12,5-23

4.9. All exploration workings, boreholes and outcrops of ore bodies must be documented at scale 1:50, in accordance with йыышаиуб жглу. The sample results have to be written to the primary documentation and checked correlatively with the geological description.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.

4.10. To study the quality of the mineral, delineate the ore bodies and the estimate the reserves, all ore intervals revealed by exploration workings and determined interval in natural outcrops must be sampled.

4.11. At evaluation stage or early stage of exploration works, the choice of sampling methods (geological and geophysical) and methodic is based on data related to geological setting's features of the deposit, as well as the applied technical characteristics of that time. Results of nuclear geophysical survey can be used as comparing tool for sampling of niobium, tantalum, and REE deposits. In this case, using geophysical survey and taking its results of measurements for estimating reserves and resources, must follow the normative-methodological documents and rules optimal for this requirement.

Selected methodology for sampling and sampling ways should ensure the confidence to get results with high productivity and economically viable. When using several types of sampling (core, channel and strip), it is important to use and follow the documentation methodology to determine the quality and sample processing and access the confidence of sampling methods.

In order to reduce the labor and cost of sampling and processing, before sampling procedure should get an information or measurement data of borehole logging, nuclear physics measurements, or magnetic and other surveying (ore body thickness is reliably determined by gamma-gamma logging in pegmatite deposits in bedrock).

4.12. Sampling of exploration profiles shall meet the following conditions:

- The sampling grid must be consistent; its density is determined by the geological setting's features of the studied areas of the deposit; generally, it is defined by exploration experience of similar deposits but in a new areas, it is determined by attempts. Samples must be taken in the direction of maximum variability in mineralization. If the ore bodies are crossed by boreholes at an sharp angle to the direction of maximum variability (in this case, it will be appear some doubts about the representativeness of sampling), the sample results have to be controlled by comparison way and signed the possibility of using these sections in the reserve estimation;
- 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; in the exploration workings, it shall be sampled ore body outcrops and their weathered parts, too;
- Natural types of ores and mineralized rocks should be tested separately – sections; the length of each section (ordinary sample) is determined by the internal structure of the

ore body, the variability of the mineral composition, textural and structural features, physical-mechanical properties and other properties of ores. The length of the sample should not be exceeding the minimum thickness that distinguished type and varieties of ore and the maximum thickness of the layers with blank and non-conditional content within the ore contours.

- The sampling (core and sludge) method from the borehole depending on type and quality of drilling. Intersections with different core (sludge) yields should be sampled separately. In the case of sample erosion, core and sludge that containing erosion materials are sampled and analyzed separately. The main systematic/persistent errors in determining the Ta_2O_5 content of tantalum-containing pegmatite deposits are because of deteriorating core yields and the presence of brittle crystalline particles of tantalite (wodginite, microlite, etc)

- In case of sampling from excavation it is required to take 2 walls of vertical and horizontal excavations that intersecting the whole thickness of the ore body. Samples should be taken from the face of excavation that goes along the ore body. The sampling distance is mainly 1-2 m (increasing the sampling distance should be validated by results of experimental work) when take the samples from the face of excavation that goes along the ore body. All samples shall be placed at consistent height determined in prior for the horizontal excavation on steeply dipping ore body. Parameters using for sampling have to be confirmed by experimental work. In order to use the sampling method for exploration excavation, it is necessary to study the possibility of ore and non-ore minerals' adhere or stain.

- Sampling information of vertical and horizontal excavation that could not reveal whole thickness of ore bodies, should not be used for reserve estimation. The sampling of the vertical excavation that intersected the ore bodies across its whole thickness, must be chosen based on distribution features of REE, niobium and tantalum enriched zones (ore columns).

- The results of geological and geophysical sampling from boreholes and excavations will be used to assess the regularity of the mineralization and to determine the presence of radioactivity. Therefore, large-scale sampling should be taken in equal steps in each section

4.13. The quality sampling for each accepted method and for the main types of ores should be systematically monitored, assessing the accuracy and reliability of the sampling results. The position of the samples relative to the geological structure elements and the reliability of delineation of ore bodies' thickness should be checked in periodic manner, and the actual sample weight should be calculated based on the actual diameter and core recovery (deviations should not exceed ± 10–20% taking into account the variability of ore density).

Accuracy of groove sampling should be controlled by taking same type of sampling method, but in case of core sampling it is controlled by the second half (duplicates) of the core. The confidence of sampling method and methodology are controlled by samples that are more representative, specifically, by comparing the results of taken bulk (strip) samples. For this purpose, technological samples collected for determination the ore-processing characteristic, information of bulk samples taken for definition of volumetric weight as well as results of exploitation should be used too. The amount of controlling sample should be sufficient for statistic processing and making conclusionwhether systematic error exists as well as to develop correction coefficient if applicable. More attention needs to be paid to drilling quality control in pegmatite deposits, and more deep excavations or “resurgent” excavations are needed

4.14. Sample preparation for laboratory analyses must be performed according to the scheme that processed based on mineral distribution, its grain size and form. The main and control samples are processed according to the same scheme. The quality of the sample preparation procedure should be monitored regularly for each activity, such as the basis of "K" coefficient and the following condition of the processing scheme. The cleaning of the crushing equipment should be specially controlled when doing sample preparation of samples with significantly different content of niobium, tantalum and REE. The sample preparation procedure of bulk samples is carried out according to a special program/rule

4.15. Study of chemical composition of ore must be conducted to identify all main profitable elements, as well as trace, by-products and toxic impurities. Chemical copositon of ore must be ananlysed laboratory analyses such as chemical, optical and physical and other methods in accordance with national approved standards. The chemical composition of the ore is carried out in accordance with the requirements of the guidelines for the study for the purpose of comprehensive study and exploitation of minerals. If this type of methodological recommendation is not developed, a similar one can be used, for example, the Russian “Methodological Recommendations for the Comprehensive Study of Locations and the Calculation of Reserves of Combined Mineral Reserves and Components, 2007”

4.16. All samples must be analysed and determine the amount of main profitable components. Loparite must be determined in loparite ore. In loparite ore, the by-products, toxic impurities, and loparite composition, which are not considered to be differentiated by the thickness of the ore body, are determined mainly in grouped samples. Principles for determining the integration of regular samples into the grouped samples or composites, their distribution condition and general quantification are designed to ensure thatequally involved in identifying the accompanying and toxic compounds for the major ore types as well as can represent the change patterns of content along to dip and strike of ore body. XRD analysis should be done to determine the oxidation level of primary ore and contour of oxidation zone.

4.17. The quality of the sample analyzes should be systematically checked, and the results of the monitoring should be processed in a timely manner. Analytic monitoring of sample should be carried out independently of laboratory internal monitoring throughout the entire exploration period on the deposit. The results of tests for all major, accompanying and slag-forming components and harmful impurities are subject to control.

4.18. To determine the values of random errors it is necessary to carry out internal control by analyzing encrypted control samples taken from duplicates of analytical samples in the same laboratory that performs basic analyses. To identify and assess possible systematic errors, external control should be carried out to a laboratory, which has the mandatory of control. For the external controlling analyses, it has to be selected duplicates of analytical samples stored in the main laboratory and passed internal control. In the presence of standard samples of composition similar to the samples under study, external control should be carried out, including them in encrypted form in a batch of samples that are submitted for analysis to the main laboratory. Samples sent for internal and external control should characterize all types of ore and classes of contents. All samples showing abnormally high content of the analyzed components, including "ultra high grade", are sent to internal control.

4.19. The amount of internal and external control should ensure the representativeness of the selected samples for each content class and exploration period (quarter, half-year, year). When allocating classes should take into account the parameters of the standards for the reserve estimation like as cut-off grade and minimum productive grade. In the case of a large number of analyzed samples (2000 and more per year), 5% of the total number of samples is sent to control analyses; with a smaller number of samples for each selected class of contents, at least 30 control analyses for the controlled period should be performed.

4.20. Data rrocessing of internal and external control results for each content class is carried out by periods (quarter, half-year, year) separately for each method of analysis and laboratory performing basic analyses. Evaluation of regular error evaluations as a result of the analysis of standard composition samples is carried out in accordance with the statistical methodology. Acceptable maximum margin of error (Standard Deviation) identified as a result of internal control should not exceed the limit values shown in Table 11. Alternatively, it exceeds the amount, the results of the analysis of the content group and the results of the analysis of the laboratory for certain periodwill be reversed and the samples will be re-analyzed with internal geology control. At the same time, the testing laboratories should identify the causes of their work and eliminate mitigation measures.

4.21. In case of detection of systematic differences between the results of the analysis of the main and the controlling laboratories according to the external control, arbitration control is carried out a laboratory that accredited in International level and certified to such kind of activities. The analytical duplicates of ordinary samples stored in the laboratory (in exceptional cases, the remains of analytical samples), for which there are the results of ordinary and external control analyses, are sent to arbitration control. 30-40 samples for each class of contents for which systematic discrepancies are revealed are subject to control. If standard sample are 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, 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 coefficient into the results of the main analyses. Without arbitration analysis taken by Laboratory with International Accreditation, the introduction of correction factors is not allowed.

Table 11. The acceptable maximum margin of error (Standard Deviation)

Composition	**Ore content, group*, %**	***The acceptable margin of average square error*, %**	**Composition**	**Ore content, group*, %**	***The acceptable margin of average square error*, %**
1	2	3	4	5	6
Nb_2O_5	1–10	9	Li_2O	0,2–0,5	13
	0.5–1	11		0.1–0.2	17
	0.2–0.5	13		0.05–0.1	22
	0.1–0.2	16		0.01–0.05	30
	0.05–0.1	20	Rb_2O, Cs_2O	0.2–0.5	17
	0.02–0.05	23		0.1–0.2	22
	<0.02	30		0.05–0.1	25
Ta_2O_5	0.1–0.5	12		0.01–0.05	30
	0.05–0.1	17	P_2O_5	20–30	2
	0.02–0.05	22		10–20	3.5
	0.01–0.02	25		5–10	4
	0.005–0.01	30	Zr_2O	>3	3.5
	<0.005	30		1–3	6
$\sum TP_2O_3$**	>10	4.5		0.1–1	15
	1–10	7		<0.1	30
	0.5–1	10	Sr_2O	10–40	6
	0.2–0.5	13		2–10	7.5
	0.1–0.2	20		0.5–2	16
	0.05–0.1	25		0.1–0.5	23
	0.005–0.05	30	U	0.03–0.1	6.5
	<0.005	30		0.01–0.03	8
BeO	0.5–1	7		<0.01	15
	0.2–0.5	10	Th	0.03–0.1	8.5
	0.1–0.2	12		0.01–0.03	10
	0.05–0.1	15		<0.01	20
	0.02–0.05	20	** If the content groups distinguished at the deposit differ from the content groups specified in this table, the acceptable maximum margin of error shall be determined by interpolation*		
Sn	0.2–0.5	10			
	0.1–0.2	15			
	0.05–0.1	20	*** In case of independent REE, the acceptable margin of average square error must be differentiated according to the amount of statistic data*		
	0.025–0.05	25			
	<0.025	30			

4.22. According to the results of control performed on sampling procedures including sampling, sample processing and analysis, it shall be evaluated possible error in determination of ore intervals and their parameters.

4.23. The mineral composition of ores, their textural and structural features and physical properties should be studied using mineralogical, petrographic, physical, chemical and other types of analysis. It also provides a quantitative assessment of their distribution along with specific mineral definition. Particular attention should be paid to the size and hardness of the ore minerals, spatial relationships of mineral grains (mineral aggregation, size, etc.) that make up the main mineral of the deposit with each other and with other minerals. In the case of radioactive ores, the relationship between radioactive minerals and rare metal bearing minerals (especially tantalum) must be studied. In the case of significant changes in ore minerals, special study must be conducted to determine their causes and to identify individual REE bearing minerals. Mineralogical studies include the distribution of primary and secondary minerals as well as toxic impurities, and must identify mineral composition and their assemblage.

4.24. The determination of physical and geotechnical characteristics (volumetric weight, natural moisture, porosity and granulometric composition of the ore) of the ore or rocks of the deposit and non-conditional parameters within the ore are determined using the appropriate methodology. The volumetric weight of massive ore is determined mainly based on the representative paraffin-coated samples and controlled with the results of whole or bulk sample from the ore bodies.

The volumetric weight of the loose and strongly fractured and porous ore, is determined for the entire ore. Also, determination of the volumetric weight can be made by method of absorption of scattered gamma radiation at presence of the required amount of verification work. Simultaneously with the determination of the volume weight on the same material is determined the moisture content of the ore. The samples and specimens for determination of volume weight and moisture content should be subjected to mineralogical studies and analyzed for major components.

4.25. As a result of the study of chemical, mineral composition, texture and structural features and physical properties of ores, their natural types are determined and industrial (technological) types requiring selective extraction and separate processing are planned on preliminary basis. The final determination of industrial (technological) types and ore grades are made onthe basis of the results of technological study of the natural varieties identified at the Deposit.

Five. Study of technological property of ore processing

5.1. In order to conduct study of ore processing technology of REE, niobium and tantalum deposits, first of all, representative sample for technological test must be taken from all types of natural (mineralogical) and technological ore, in accordance with accordance with appropriate methodology and rules.

5.2. The technological properties of ores, as a rule, are determined on laboratory and semi-industrial conditions on mineralogical-technological, minor technological and laboratory, integrated laboratory and semi-industrial samples. For ore, which is has easy processing technology, can be analogically used, existing experience in industrial processing for easily dressed ores, it is allowed to use an analogic way confirmed by laboratory research results. For difficult-to-dress or new types of ores, which have not been subjected in ore-processing, technological studies of ores and their products or new types of ores are completed according to special programs that agreed by the interested organizations and companies, in case of necessity.

5.3. Preliminary tests will be carried out at various stages of geological exploration project. The ore will be sorted into large coarse ores in a special hopper, and small grained ore (-200 ~ +20 mm) will be enriched using radiometric separation and gravitational beneficiation based on their radioactive properties. Depending on the nature of the ore and the results of the processing experiment, the coarse-grained ore can be pre-sorted or the mined ore can be enriched in bulk by the main production processes (gravity, flotation, magnetic separation, leaching). Furthermore, the study of deep ore processing should take into account the feasibility and economic viability of incorporating the pre-enrichment phase into an integrated technological scheme.

5.4. For the selection of technological types and sorts of ores, geological and technological mapping is carried out, in which the sampling grid is selected depending on the number and frequency of alternation of natural varieties of ores.

5.5. The study of primary ore processing of REE, niobium and tantalum determines the degree of oxidation of the ore, mineral composition, structural-textural properties, physical and chemical properties of minerals, and the associated profitable and toxic impurities. In addition, the properties of ore and concentrate (radiometric separation) products are determined using technological-mineralogical methods

5.6. The results of REE ore processing experiment depend on the representative characteristoc of ore sample, chemical composition and mineralogical assemblages of ore. Almost all REE, niobium and tantalum ores and mineralized rock mass contain radioactive elements such as uranium and thorium, which are mainly present in naturally occurring isotopes. Ore mineral assemblage varies in wide range depending on the type of deposit, therefore before choosing the technological processin experiment, the ore composition should be studied with an optical microscope and the latest advanced methods of mineralogy as Laser Raman spectrometry, X-Ray Diffractometer, SEM-EDS and EPMA (Electron Probe Micro Analyser) should be used to determine the type of ore, type of appearance of REE, niobium, tantalum and other minerals.

5.7. Mineralogical and technological and technological samples, selected along with a specific grid, should be characterized by all the natural types of ores identified at the deposit. According to the results of their testing, geological and technological identification of ores and sorts of the deposit is carried out studies determining industrial (technological) types and ore grades, the spatial variability of the material composition, physical, mechanical and technological properties of ores within the selected industrial (technological) types, and on the background of them, geological and technological maps and sections will be compiled for the deposit

5.8. The laboratory and integrated laboratory samples shall be subjected to study the industrial (technological) properties of all selected industrial (technological) types of ores to the extent necessary to select the optimal technological scheme for their processing and determine the main technological indicators of enrichment and the quality of the products obtained. It is important to determine the optimal degree of grinding ores, which will ensure the maximum extracting of valuable minerals with minimal waste and losing them into tails

5.9. Semi-industrial technological samples are used to check the technological schemes and clarify the indicators of ore enrichment obtained in laboratory samples. Semi-industrial technological tests are carried out in accordance with the program developed by the organization performing technological research, together with the subsoil user (license holder) and agreed with the project organization. Sampling is carried out on a special project.

5.10. Integrated laboratory and semi-industrial samples should be representative, i.e. meet the chemical and mineral composition, structural and texture characteristics, physical and other properties of the average composition of ores of this industrial (technological) type, taking into account the possible dilution with ore-bearing rocks. The structure of the granulometer should also be in line with the proposed mining scheme for the deposit.

5.11. Technological-mineralogical method to study of primary ore and radiometrically separated products must include the degree of oxidation of ore minerals, ore mineral assemblage, chemical composition of ore mineral, structural-textural characteristics, physical-chemical properties, their level of differentiation (emission, detection) and presence of by-product profitable mineral and toxic mineral. In addition, to sieve analysis must be carried out on various group and type of ore, in order to determine the crushing and grinding quality of the ore, the decomposition rate of the mineral phases, and the washability of the ore. Also must do gravitation experiment on washed ore and washed sludge as well as magnetic separation test on fine grained part of ore. As a result, ore processing technology must be chosen and determine the number and stages of crushing and grinding. The experiment must determine the best ore processing method ore concetnrates is and semi-produced products and possible way to separate profitable components.

5.12. Ore processing technological properties of REE, niobium and tantalum deposits directly depend on the mineral composition of the ore, their structural and textural features, the amount of TR_2O_3, Nb_2O_5, Ta_2O_5 content, their relationship, and the amount of radiation

- In order to processing of REE ore the gravitational or flotation method (and a combination) is mainly used to concentrate, and in some cases the radiometric method can be used, depending on the amount of natural radiation. REE content in the extracted concentrate ranges between 30–70%. This concentrate is subjected to chemical-metallurgical processing (by sulfation or chlorination), then REE compunds and oxides will be separated by ion exchange chromatography. After this procedure Rare earth metals and high-quality alloys will be produced by metal-thermal and electrolytic method. This is the final product that meets for the requirements to use in the metallurgical industry. Radiation treatment of this technological process requires a separate operation
- The processing scheme of pyrochlore type niobium ore (carbonatite and its weathering surface) depends on the size pyrochlorie contained in the ore.

If pyrochlores is bigger or coarse in size it can be processed by gravitation, in case of medium sized pyrochlore it is recommended to use gravitation-flotation method, but for finegrained pyrocholre flotation is better. Depending on the physicochemical properties of the ore minerals contained in the ore, the selected scheme can be combined with magnetic, electrical, chemical and other methods of processing. The Nb_2O_5 content of pyrochlore concentrate is about 60%. The end product of pyrochlore and columbite concentrates is ferroniobium (FeNb) which contains 65% niobium, and it will be used for steel industry to improvequality of steel. Aluminiobic ligatures (re-processed ferroniobium) can be produced from low quality concenrate (low Nb_2O_5 content) obtained by aluminothermic methods.

- Simple composition tantalum ore of is processed by mechanically method as gravitation. If ore has a complex mineral composition (separation of accompanying components) it can be processed by gravitational-flotation or other methods (magnetic, electromagnetic, polarity gradient, radiation) should be used in combination. Tantalum concentrate will be produced by gravitational extraction, and its tailing will be treated by floatation to produce other by-products. If use polarized gradient by combustion will get final product of tantalum concentrate.
- Loparite ore is proceed be gravitation method. In order to get final concentrate product magnetic and electrical separation can be used. The product contains 93-98% loparite and the ore recovery is 75-80%. Concentrate composition is as following: $\sum TR_2O_3$-36-38,Ta_2O_5-0.5-0.6, Nb_2O_5-7-8, TiO_2-38-42, $Fe_2O_3 \leq$ 2.5, SiO_2-2,9, ThO_2- 0.6. Loparite concentrate is chemically and metallurgically processed using chlorine technology to produce the following products. These include: Chloride compound of REE, niobium (Nb_2O_5) and tantalum (Ta_2O_5) oxides, and titanium tetrachloride. Chloride compound of REE can be re-processed by hydrometallurgical method to produce independent oxides, pure metals and other products

5.13. Result of the study of the technological processing characteristics of the ore, determines the main data required to obtain a technological scheme for the processing of the ore and the extraction of all types of industrially significant minerals contained in it have been identified. Types and grades of ore production (technological) must meet pre-planned condition parameters, basic parameters of processing and chemical processing technology (gravitation, magnetic separation and flotation of concentrate recovery and its quality depend on the content of rare metals, other ancillary minerals and toxic impurities) must be identified. In addition, tailings dams and detoxification have been studied, taking into account special operations for the processing of concentrates to extract rare metals and accompanying minerals, as well as the consumption of reagents used in their production (grain size and residual concentration of reagent). The reliability of the technological scheme received as a result of the semi-production test is evaluated by the balance of technology and the final product during production. The difference between the test results and the product balance shall not exceed 10% and shall be proportional to the mass of metal in the concentrate and to the waste. Re-processing parameters should be compared with those of modern processing factory. The quality of the concentrate must be regulated over a period of time in accordance with the agreement between the miner and the metallurgical plant, or with appropriate standards and specifications. Table 12 shows the technical requirements for concentrates in Russia. At present, Mongolia does not yet have national and sectoral technical standards for REE concentrates.

5.14. In the case of accompanying by-product, there is no “Methodological Recommendations for Comprehensive Study of Deposits and Estimation of Mineral and Mineral Reserves” to be approved by the Ministry of Mining and Heavy Industry of Mongolia. In accordance with the “Guidelines for Estimating Reserves”, the balance and distribution of ore products to be processed should be determined to determine the conditions under which they can be extracted and whether they are economically viable

5.15. The proposed technological processing scheme should include recommendations for the possibility of recycling concentrate waste and water used for processing, for example, processing concentrate waste into microbord, and wastewater treatment.

Table 12. Requirements for the niobium and tantalum concentrate

Concentrate and its components	**Content, %**			
	Sort I	**Sort II**	**Sort III**	**Sort IV**
Loparite concentrate				
- The minimum content of loparite	90	90	90	65
- The minimum content of Nb_2O_5 and Ta_2O_5	8	8	8	8
- Maximum content of phosphorus	0.016	0.1	0.3	0.5
- Maximum content of silica	2.5	2.5	6	8
Pyrochlore concentrate				
- Maximum content of Nb_2O_5 ба Ta_2O_5	38	–	–	–
minimum content				
- Maximum content of moisture	1	–	–	–
- For 1% of Nb_2O_5 and Ta_2O_5 sum				
Maximum content of accompanying component				
SiO_2	0.32	–	–	–
TiO_2	0.32	–	–	–
P	0.0025	–	–	–
S	0.003	–	–	–
Tantalumconcentrate				
- Maximum content of tantalum	40	26	17	5
- Maximum content of silica	No requirement	7	7	10

Six. Study of hydro geological, geo-technical and geo-ecological and other environmental conditions

6.1. Depending on the natural, climatic and geographical location of Mongolia, and location of ore bodies above or below the erosion base/erosion level create different conditions hydrogeology, engineering-geology and geo-ecology and its nature.

To carry out hydrogeological condition of there, niobium and tantalum deposit study shoul follow "Instruction for conducting Hydrogeological Surveys during Thematic, Medium and Large-scale Hydrogeological Mappingand Mineral Resource Exploration Works, and Requirements to the Exploration Activities" approved by order of No. A/237 on December 12^{th}, 2017 by Minister of Mining and Heavy Industry, Mongolia.

6.1.1. Results of previous study on the hydrogeological study of the deposit and its surrounding area and additional hydrogeological observation during exploration project must be expressed and discussed on Chapter of "Hydrogeological condition of deposit".

6.1.2. The hydrogeological study will be conducted for the deposit to determine and study the main aquifers that capable to floats the deposit and define the watered areas and zones. In addition, the mine water use or disposal method should be resolved by the hydrogeological study.

6.1.3 The specific hydrogeological conditions of REE, niobium and tantalum deposits are determined by the amount of radioactive elements contained in the chemical composition of the aquifer water around the ore body.

6.1.4 The hydrogeological conditions of the deposit are classified as normal, medium and complex

- Deposits with normal hydrogeological conditions include deposits with a stable aquifer, hosted by hard rock, and the amount of water entering the mine does not exceed 1000 m^3/h. In such deposits, exploration and borehole water level measurements, borehole wall stability, leachate leakage measurements, sedimentation measurements, yield determination, pressure level (artesian) aquifer crossings, and, if necessary, hydrogeological observations are necessary. A number of boreholes will be drilled and equipped to observe the aquifer
- Medium-hydrogeological condition deposits include those with tectonic faults and aquifers in the fault zone, which are likely to be flooded if the mine is opened, and where the volume of water entering the mine is up to 1,500 m^3/h
- Complex hydrogeological conditions deposits are identified be water-bearing rocks are strongly affected by tectonic erosion and disintegration, contain large amounts of groundwater, and contain more than 10,000 m^3/h of water entering the mine.

In deposits with medium and complex hydrogeological conditions, hydrogeological research will be carried out by special drilling wells, pumping and hydrogeological measurements will be carried out in 2-3 aquifers, and water level drop and recovery will be measured several times. Drill hydrogeological boreholes and conduct hydrogeological observations and measurements using a combined system of excavated boreholes to conduct temporary and long-term hydrogeological surveys

6.1.5 Hydrogeological study of deposit area must be decided following problems

- Estimation of water inflow from precipitation to the mining area by all factors, depending on the local geography and climatic conditions of the deposit
- The chemical composition of the water entering in to the deposit, the amount of radioactive elements, the condition of the water bacteria and the hydrochemical study must be performed
- Using os surface water and mine drainage should be coordinated with local water use and protection organizations, state sanitary inspection and land inspection organizations
- In case the mine water cannot be supplied to the river water or it is prohibited, the mine water reservoir shall be constructed based on the feasibility study of the deposit and the amount of water in it shall be calculated in accordance with relevant regulations and methodologies
- Evaluate the mine's infiltration to protect the mine from flooding, assess whether it can be used for production, assess the impact on groundwater accumulation in the deposit area, and make a reasonable choice of the location of the reservoir and tailings dam
- Evaluate potential sources to provide the technical water supply needs of future mining and processing plants, and assess the environmental impact of mine wastewater

6.1.6. The results of the hydrogeological survey will provide recommendations on the processing of the mine planning in the following areas: to drain geological massif, water drainage, use of drained water, source of water supply and environmental protection issue.

6.2. The main purpose of the geo-technical survey of the deposits during the exploration is to provide required information for developing the mining project (to make basic calculation of open-pit and pillars and to process passport of drilling-blasting and mounting works) as well as improving the safe access of mining excavation works.

6.2.1. In results of the research on the engineering-geological condition of the deposit, it has to determine following items

- Physical-mechanical properties that define the strength of ore and host rock as well as covering sediments and must create database; (strength, porosity, moisture, radiation, density and viscosity, adhesion etc)
- Geotechnical surveys of sediments and rocks containing the deposit and ore bodies have been carried out and create a database necessary for the development of the deposit (deep seated and local faults, direction of fault and its dippuing, striking, their frequency, distribution patterns, etc)
- It is neceaasry to study seismic/earthquake activity of the deposit area, permafrost, karstification, weathering of rocks, and neotectonical, geological and natural factors that may affect mining have been studied
- The scope of the safety zone for future open pit and underground mining and the dimensions of the mine safety margin (wall slope angle and margin width), the size of

the protective block, the rock pressure and movement stability, and the geological factors that may affect them are identified

6.2.2. The geotechnical and geological conditions of the deposit area must be carried out in accordance with the methodology, instructions and procedures established by the relevant authorities.

6.2.3. Study of the geotechnical and geological condition especially for underground mining must care to correctly determine the amount of radiation, protect against radiation, and regularly measure radiation with a dosimeter

6.2.4. if there is active mining with similar hydrogeological and engineering-geological conditions of the deposit area, it can be used to evaluate by comparing its hydrogeological and engineering-geological environmental assessment

6.3. The main purpose of the geo-ecological study is to provide information on the environment and the protection of the geological environment during the development of the deposit

6.3.1. From the initial stage of exploration of REE, niobium and tantalum deposits, it is necessary to systematically study the environmental impact and plan the amount of funds required for the study and implementation of mitigation and environmental protection measures in the economic assessment of the deposit.

6.3.2. Irrespective of the method of extraction of REE, niobium and tantalum deposits, the amount of radiation depending on the uranium and thorium content of REE ore and other toxic elements such as beryllium, lithium, cesium, arsenic, bismuth, fluorine and organic compounds are considered to be ecologically and hygienically hazardous. It is necessary to pay special attention to environmental ecological research

6.3.3. The following issues need to be decided by study of ecological conditions:

- Evaluate the initial state of the environment, determine the level of natural radiation of the site, surface and groundwater, radiation and atmospheric characteristics, vegetation cover and soil condition and created a database
- Chemical and physical effects of industrial production (dust, surface and groundwater contamination by mine water, soil pollution, atmospheric pollution from various gases and aerosols, changes in radioactivity in the air, etc.), exposure to sources of pollution the size of the range, the duration of the contamination, the intensity, the frequency, and the service hazards should be anticipated
- Percentage of radon emissions in mining operations should be measured to the extent that mine ventilation is optimally planned
- The total amount of natural resources to be used for mining and processing factory (timber, water, construction materials, land to be used for the construction of main and ancillary facilities, stripping soil, non-compliant ore and stockpile stockpiles, etc.) should be estimated as realistic as possible.

6.3.4. Special attention should be paid to the protection of workforce health (radiation, pulmonary ionization hazards, geothermal conditions, etc.) in the mining and processing of REE, niobium and tantalum deposits

6.3.5 Land reclamation, or technical and biological reclamation, needs to be planned because mine rehabilitation plays an important role in environmental protection. When the deposit is mined, a special stockpile of fertile soil will be constructed to preserve its nutrients and then used for biological rehabilitation

6.4. The hydrogeological, geotechnical and geo-ecological conditions of the deposit must be studied in order to conduct geological-exploration research and establish a future mining plant, as well as to evaluate the physical, geographical, climatic and topsoil changes in the area.

6.5. Archaeological and historical monuments and paleontological excavations at the deposit site should be carried out by relevant professional organizations in accordance with established procedures and instructions

Seven. Reserve estimation of niobium, tantalum and REE deposits

7.1. Calculation and qualification of the degree of exploration on niobium, tantalum and REE deposits must be completed in accordance with the instruction "Classification of mineral resources and reserves of deposits", approved by the order No.203 of the Ministry of Mining Industry of Mongolia dated September 11, 2015.

7.2. This guideline classifies deposit reserves as geological reserves and mineable reserves depending on the factors influencing to develope. Geological reserves are calculated based on the results of exploration work, while mineable reserves are calculated based on the feasibility study of the deposit.

7.3. When estimating the geological and mineable reserves of a deposit, first of all, the reference parameters (condition) to be used in the calculation shall be determined. Then, based on this, a reserve estimation will be made. Commonly used reference parameters for reserve estimation and resource assessment are:

- Minimum production content, %
- Marginal content to constrain ore body, %
- Minimum thickness of ore body, m
- Minimum production content in the reserve estimation block, %
- Thickness of non-standard and barren rock to be incorporated into the ore body, m

7.4. In order to calculate reference parameter of reserve the market price of single element and compound oxide will be taken as main criteria. If one of the REE is predominant (high grade) in the deposit, that element can be considered as the main representative element as an adjunct to other low grade elements. This is similar to the transfer of equivalent values to deposits of multi elements (silver-alloy metals, molybdenum-tungsten-tin, etc.). From an economic point of view, such price criteria are used to calculate the reference parameter, which is the main incentive to keep the characteristics of the deposit economically viable. For clarifying, the use of a high-grade element as the main representative of a deposit will prevent that element from being absorbed into the price of the deposit's compound oxide and reducing its market value. Furthermore, it will be possible to select the most economically feasible standard option by calculating the preliminary feasibility study of the REE deposit and comparing it with other indicators.

7.5. Reserves are calculated by reserve blocks, the amount of ore in which should not exceed, as a rule, the annual productivity of the future mining enterprise. The reserve blocks of ore bodies shall be characterized by following items:

- same degree of exploration and study for reserve size and ore quality;
- evenity of geological structure, relatively stable thickness and having less variability in thickness and internal structure of ore bodies, material composition, the main indicators of quality and technological properties of ore;
- stable locations of ore bodies belonging to reserve blocks, and their locations in a same structural element; and
- common mining-technical conditions.

The reserve blocks should be divided by the horizons of mining operations or boreholes in dipping direction of the ore bodies, while along with strikes – by exploration lines (profiles), considering the planned sequence of reserve exploitation.

If it is impossible to do geometrization and contouring of ore bodies or industrial (technological) types of ores, it can be statistically determined volume of ore types that are economic reserves

7.6. REE reserve can be estimated as independent element or sum oxide ($\sum TR_2O_3$). In case of converting content of single element into trioxide (La_2O_3, Ce_2O_3, etc.), should use ratio of the atomic weight of the element to the oxygen.

7.7. Reserves are classified according to the degree of exploration, the mining method (open pit, horizontal mouth level, shaft), the type of ore production or technology, the ore grade and the economic efficiency

Additional indicators can be used to classifying mineral resources, such as the accuracy and reliability of the definition of key calculation parameters, and reasonable estimates. If it is not possible to determine the relationships and boundaries between the different types and grades of ore production, it is determined by geostatistical methods

7.8. The geological reserves of the deposit are categorized as Proved, Probable and Indicated categories. Proved reserve is noted by (A), Probable reserve is noted by (B) and Indicated reserve is noted be (C).

Proved (A) category reserves will be only calculated in Group 1 deposits with precision to the area surrounded by excavation and borehole data and do not use extrapolation. The Proved "A" category reserves in the active mining deposits are calculated based on the data of exploration and mining preparations. Proved (A) category reserves shall fully meet the requirements for proven (A) grade reserves specified in the "Mineral Resources and Deposit Classification and Guidelines" of Mongolia. According to result of the exploration project, the amount of Proved (A) category reserves in Group I deposits shall be sufficient to cover the initial investment of the extractive industry. In addition, reserves in areas that meet the requirements of the exploration grade and are ready for extraction are included in this category

Probable (B) category reserves are calculated on the detailed studied sections of Group I and Group II deposits, which meets the requirements of the "Reserve classification" standards, in results of exploration grade. The B category reserves should be contoured along with exploration works and boreholes without extrapolation; and the basic geological characteristics of the ore bodies and the quality of the ore within this contour are determined by a sufficient amount of representative data. In case If geometrization is impossible the ore body by its spatial location, shape and quality, the above parameters can be determined by geostatistical method. For deposits where the size of the ore is determined using the mineralization coefficient, the "B" category is classified at the part where mineralization coefficient is higher than the average of the deposit, the change in ore saturation is determined by the area and depth, and the spatial location, shape and specific dimensions of the ore parts. This may include sections that have been studied to the extent that they can be evaluated for selective extraction.

Probable (B) category reserves shall fully meet the requirements for Probable (B) category reserves in accordance with "Mineral Resources and Deposit Resource Classification and Guidelines" of Mongolia. The dominant part of Group II deposit reserves must be estimated at Probable (B) category.

Indicated C category reserves includes reserves in areas, within which the grid of excavation workings and boreholes meets the requirements for this category is maintained; and the reliability of the information obtained is confirmed at the new deposits by the detailized sites, and at the developed deposits by the operation data. In the deposits, where the volume of ore is determined by the ore-bearing coefficient (stockwork and large mineralized zones that contoured by sampling data), the study of the main features of the internal structure should provide clarification of the ore saturation and distribution patterns on areas of conditioned ores.

In case if geometrization the ore body by is impossible, its spatial location, shape and quality, the above parameters can be determined by statistical analyse. In this case, the distribution patterns and ore saturation of the parts that meet the requirements of this grade are studied to a reasonable extent.

The contours of C category reserve must be determined by exploration excavations, and for the most sustained and large ore bodies are determined by limited extrapolation considering the changes of the morphological characteristics, capacity of ore bodies and ore quality. The size of the extrapolation zone shall not exceed half the distance between the outputs accepted for the reserves of this category.

Indicated C category reserve is based on extrapolation boundaries (in dipping and strike directions) that determined by geophysical works, geological and structural settings, and results of studying the patterns of changes in thickness of ore bodies and REE, niobium and tantalum content in them and single ore intersections, confirming this extrapolation. For independent ore bodies – based on a set of ore intersections established in outcrops, mine workings and wells, taking into account the data of geophysical, geochemical studies and geological structures, and if it is impossible to geometrize ore bodies – statistically within the generalized contours.

Indicated C category reserve should take into account the basic status of the geological settings, the positional conditions of ore bodies and studies related to distribution patterns of changes in ore-bodies' size, shape, thickness and quality of ores. On the previously estimated areas in the contours determined by analogy with the more studied parts of the deposits, the analogy of the geological structure is established by the results of geophysical, geochemical studies, geological settings and individual exploratory intersections.

Inferred resources (P_1) are calculated for ore bodies with a small number of excavations and boreholes, and for marginal and deep parts of the ore body adjacent to the estimated reserves. The boundaries of the section being assessed for inferred resources (P_1) shall be determined based on the geological setting of the deposit and the results of geophysical surveys, based on the density of the exploration grid used for the possible (C) grade, or scattering it.

7.9. Feasibility study for mining operation of the deposit will be processed on background of the geological reserves. In results of the feasibility study completion, part of the geological reserves located within pit mining shell and remaining after dedication of mining waste and pollution is presenting the Mineable reserve, which is divided into Proved (A') and Probable (B') reserves according to requirements of "Classification and guideline of mineral resources and reserves of deposits". Depending on the mining and technical conditions of the deposit and the assurance of the validity of the resource grades, there are some cases when the geological resource category is changed up or down categories.

Proved (A') mineable reserve is based on the geological reserves of mineral resources of Proved (A) and Probable (B) categories; 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') mineable reserve is based on geological reserves of mineral resources of Measured (B) and Indicated (C) categories; 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".

7.10. The requirements for mineable reserve of the above mentioned 2 categories are essentially the same, and the differences are observed in that the Proved (A') production reserves based on geological reserves of Proved (A) and Probable (B) categories, while Probable (B') mineable reserve.

However, studies conducted on properties of ore technology for geological reserve estimation in Indicated (C) categories are relatively simple, but Probable (B') reserve requires to study at pilot testing level of production technology, if the deposit part will be exploited in future.

Potentially-economic in future reserves are calculated and considered **as resources** in the event that the feasibility study of conditions proved the possibility of their preservation in the subsoil for subsequent extraction or the feasibility of associated extraction, storage and conservation for future use. At calculation of potentially-economic in future reserves, it has to be determined the reasons (economic, technological, hydrogeological, ecological, etc.) of classification of the reserves into the current class is made.

7.11. When calculating reserves by traditional methods (geological blocks, sections, etc.), samples with abnormally high content of REE, niobium and tantalum ("ultra high grade" samples) should be identified, their impact on the average content of exploration sections and reserve blocks should be analyzed and, if necessary, their impact will be limited. Parts of ore bodies with high grade and increased thickness should be distinguished into independent reserve blocks and subjected to more detailed exploration.

In case of active mining deposits, the results of comparison of exploration and exploitation data, including features of changing the distribution of samples by REE content classes as the exploration grid gets denser, should be used to determine the level of "hurricane" values and methods of their replacement

7.12. In active mining deposits, it should be separately estimated the ore reserves being uncovered, prepared and ready to exploit, as well as being in the security pillars of capital mining workings, by reserve classifications in accordance with their degree of study.

7.13. The ore reserves that closed in the zones including security pillars of water reservoirs and water flows, settlements, capital facilities, agricultural facilities, and in protected zones of natural reservation, monuments of nature, history and culture, are estimated referring into resource in accordance with approved standards.

7.14. On deposits, which are under mining activity, for control of completeness of working off of earlier approved reserves and justification of reliability of newly estimated reserves, it is necessary to make comparison of reserve data of exploration and operation worksconducted to conditions of ore body presence, morphology, thickness, internal structure of ore bodies and maintenance of useful components in accordance to approved regulations.

The comparing materials must present the contours of reserves that previously approved by the state expertise organization and of the depleted reserves (including mined and left in pillars), written off reserves as lacking confirmation, area contours of increasing reserves, as well as data on reserves listed on the state reserve balance (including current remainder reserves previously approved by the authorized organizations); and tables of reserve-movement (by categories, ore bodies and the deposit as a whole). And the reserve balance of ore and metal in the contour of depleted reserves are presented, reflecting the change in reserves approved by the Mineral Resources Professional Council, during further exploration. And the losses during production and transportation, output of marketable products and losses have been presented in the list, during ore processing. The results of the comparison are accompanied by graphics illustrating the change in ideas about the geological conditions of the Deposit.

If the exploration data are generally confirmed by the development or the existing minor differences do not affect the technical and economic indicators of the mining enterprise, the results of geological and (topo) surveying calculation can be used to compare the exploration and development data.

7.15. If the ore reserves and quality of the certain deposit is approved by Mineral Resources Professional Council have not been confirmed during the mining activity, it is necessary to introduce correction factors in the previously approved parameters or It is necessary to clarify the resource estimates based on the completion exploration and exploration data and to assess the credibility of the information obtained as a result of these activities reserves.

The comparative analysis is based on the estimated

Result of comparative analyses must be discussed by Mineral Resources Professional Council and explain the reason why there is difference in reserve estimates (reserve estimation area, mineral content, ore body thickness, mineralization coefficient, volume weight, etc.) and determine how the size and quality of the ore has changed as a result of the completion of exploration and mining.

7.16. In recent years, estimation of reserves of ore deposits, widely applied Kriging method of geostatistical modeling to study the patterns of spatial distribution of the studied characteristics (concentrations of the useful components, thickness of ore intersections, meter-percent value)

The effectiveness of geostatistic method is largely stipulated to the quantity and quality of the initial exploration data, the methodology of primary data analysis and modeling that meets the individual geological features of the structure of the explored deposit (the laws of distribution of calculation parameters, the nature of the trend and anisotropy, the influence of structural boundaries, the structure and quality of experimental variograms, the parameters of the search ellipsoid, etc.).

When using the geostatistic method the number and density of the exploring intersections must be sufficient to substantiate the optimal interpolation formula (for two-dimensional modeling – at least several tens of exploring intersections and for three-dimensional – at least the couple hundred samples). It is recommended that study of the properties of spatial variables must be in the detail areas.

The evaluation of variograms is made on the basis of testing data on through ore intersections for vein type mineralization, and on composite samples, the length of which is consistent with the bench height for stockworks and powerful mineralized zones, and of sampling intervals – in cases where there is no possibility to study the vertical variability of mineralization in composite samples.

When building a geostatistical block model of the deposit, the maximum possible size of the elementary calculation block is selected based on the planned production technology, the minimum size (mining minimum unit block) is determined by the density of the exploration grid of observations created at the deposit (it is not recommended to take the size of the sides of the elementary block less than ¼ of the average density of the grid).

The results of reserve estimation can be represented in following two forms:

- in the calculation on the same (or identical) and equi-oriented blocks, must create a table of estimation parameters for all elementary unit blocks, together with the values of the variance of kriging;
- in the calculation of the major geological blocks having individual geometry, each block needs to be spatially georeferenced and have a list of samples within the area of influence.

All digital data (sample information, coordinates of samples and ore sections, digital analysis of variograms, etc.) should be presented along with the results used by the software which are used for reserve estimation and geostatistical analyses. The models built by each variance directions of variograms and experimental variograms shall be clearly shown in the form of drawings and notes and attached to the report

It is believed that geostatistical method of reserve estimation presents the best opportunity to establish evaluation of the average contents of REE in the blocks, ore bodies and deposit as a whole without special techniques to reduce the impact of "hurricane" samples, allowing to decrease the errors of delineation of ore bodies with very complex morphology and the internal structure and optimizing the technology of the deposit development.

At the same time, geostatistical methods of reserve calculation should be strictly controlled in their application and obeyed to peculiarities of the geological structure of the deposit. In any case, the results of geostatistical modelling and evaluation should be verified by comparison with the results of traditional reserve estimation methods done on representative parts.

7.17. Geostatistical estimation of of reserves, requires to provide the ability to view, verify and correct the original data (the coordinates of the exploration workings, inclinometer data, elevation of contacts, the results of sampling) and results of intermediate calculations and constructions (list of ore intersections distinguished in accordance with the reserve estimation standards / conditions; geological sections or plans with the contours of the industrial mineralization; projections of ore bodies on a horizontal or vertical plane; catalog of calculation parameters for blocks, benches and sections) and summary results of reserves calculation are able to be checked. Produced documentation and computer-configured graphics must meet the existing requirements for these documents in composition, structure, form, etc.

7.18. Reserve estimation of an accompanying profitable minerals and compounds must be carried out in accordance with the approved regulations. Report containing reserve estimation shall be compiled in accordance to the "Content of Report about Results of Exploration Works on Mineral resource deposits, and Requirements to it" approved by order No. 114 of the Director of Mineral Resources Authority of Mongolia dated on September 9th, 2009, and presented to session of Mineral Resources Professional Council in the prescribed manner.

Eight. The study level of deposit

8.1. According to appendix of Minister of Mining's order of 203, dated on 11th of November 2015, any deposits (its parts) areclassified into following two items: evaluated deposits and explored deposits depending on theirs study level. In addition, the appendix provides the requirements to the estimated reserve and resources by prospecting and exploration works. The study level of the evaluated deposits is estimated by whether there is requirement to continue the exploration work conducted at objects. Moreover, the study level of the explored deposits is estimated by preparedness of the deposit for exploitation.

8.2. As a result of the geological-exploration work carried out at the evaluated REE, niobium and tantalum deposits: whether there is a need to carry out the exploration phase, the issue of potential industrial value of the deposit, the overall size of the deposit, as well as identifying the most prospective areas for the next exploration and mining operations etc must to be determined.

The conditional parameters using for reserve estimation should be based on feasibility study for all newly discovered deposits and it should be sufficiently established for making preliminary geology-economical assessment for entire deposits and its parts. Identified resource of the evaluated deposit is "P_1" category and geological reserve of some part is included to the Indicated (C) category.

Mining methods, systems, and assumptions about the potential extent of the deposit will be considered extensively, based on similar subsoil use projects. The scheme of ore processing technology for the complete use of mineral resources, the potential recovery and quality of the product will be determined on the basis of laboratory technology tests. The cost of capital investment to build the plant, the cost of the product and other economic indicators will be calculated on the basis of a comparison (similarly) with the performance of similar projects

In order to Evaluate the industrial significance of mineral resources, mining and drinking-water supply issues reflect preliminary based on existing, exploration and other potential sources. In addition, mining operation's impacts to the environment should be considered and evaluated.

The experimental-production mining operation should be carried-out for the evaluated deposits to study the theirs shape of ore body and ore composition, to develop an ore enrichment scheme and to make a detailed survey. The experimental-production mining operation may have been carried out within the framework of a project of the exploration stage based on permission of state supervisions on mining and environmental issues for 3 years. Duration and amount of the experimental-production mining operation, shall be agreed with the state ecology, technology and nuclear inspection agencies. In every certain requirement for carrying out the experimental-production mining operation, its purpose and solving issues shall be determined.

Conducting of experimental-production mining operation is usually dictated by the need to identify the features of the geological structure of ore bodies (variabilities of morphology, internal structure and elemental composition), clarifying geological and mining conditions, configuring out ore mining technology, ore-enrichment and processing methods (distinguish primary and technological types of ores and their relationships).The solution of these problems is possible only at the opening of the ore bodies at considerable depth and length.

The experimental-production mining operation must also be resorted to when introducing new methods for ore mining (i.e. borehole hydraulic mining of loosened ores from large and small depths), as well as when developing new unconventional ore types. In addition, the experimental-production mining operation is expedient in the development of large and giant deposits, on which, before proceeding with the construction of large factories, the developed technological scheme is tested and improved in small processing plants.

8.3. On the explored deposits the quality and quantity of reserves, their technological properties, hydrogeological, mining and environmental conditions of development should be studied with boreholes and excavating works with completeness sufficient to develop a feasibility study of the decision on the procedure and conditions of their involvement in industrial (mining) development, as well as the design of construction or reconstruction on their basis of mining exploitation.

The explored deposits should meet the following requirements according to the degree of study:

- To provide possibilities to classify the most parts of the resource as the appropriate category for the complexity of geological setting of the deposit;
- The following items should be studied in detail with the level of satisfaction: optimal technological design for all industrial significant components of economic types and sorts; trend to use factory waste and rational version to store them;
- Sufficiently exploring and assessing the reserve of associated minerals, and minerals-containing useful components including, cover sediments and groundwater, to include them in terms of geological reserve or resources on a standard basis, to quantify the reserve or resources and to determine the potential trend to use;
- Hydrogeology, engineering-geology, geocryology, geo-technical and other natural conditions should be studied sufficiently accurateproviding 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 setting, forming condition of ore bodies, their shapes, quantity and quality of the reserve should be approved by detailed work carried out on parts that can fully representative the deposit, andin each case, the size and location of the part should be defined depending on the geological features;
- 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 in 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.

Nine. Re-estimation and reconnaissance of deposit reserves

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 explorationand mining operation, the unapproved amount of deducted and deductible reserves, and alsothe 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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1.
2.
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APPENDICES

Appendix 1.

Parameters used to determine the complexity of the geological structure of mineral deposits

Quantitative characteristics of variability of the basic properties of mineralization can be used for classifying certain deposit to a particular group. Exploration system and density of exploration grid are depended on several factors of nature: locating conditions of the ore body and the structural and geological characteristics (shape of ore body and its changes and characteristic of contacts) and distribution of useful component (the level of change in mineral quality within ore bodies).

There are main parameters to indicate the complexity of ore body: ore presence coefficient (K_{p}) in ore intervals, complexity coefficient of mineralization (q), variability coefficient of thickness of ore body (V_m), and variability coefficient of conten t(V_C).

The ore presence coefficient (K_{p}) or mineralization coefficient is determined by the quotient of the boreholes and excavation-resulted length (l_p) of the mineralized interval divided by the total length of profile within productive mineralization zone (within the boundary of the economically valuable mineralization zone- l_o).

$$K_{\text{p}} = \frac{\sum \ell_{\text{p}}}{\ell_{\text{o}}}$$

The complexity coefficient of mineralization (q) is determined by the quotient of the total number of profiles revealing mineralization (N_p) divided by the total number of exploration profiles (where:

N_x – number of excavation and drill holes revealing mineralization;

N_{xz}- number of excavation and drill holes revealing no mineralization;

N_3 – number of excavation and drill holes outside the boundary)

$$q = \frac{N_р}{N_р + N_в + N_з}$$

The variability coefficient of thickness of ore body (V_m) and variability coefficient of content(V_C) are calculated by a commonly used method of exploration information and expressed in percentages.

$$V_m = \frac{S_m}{m_д} \bullet 100 \; V_C = \frac{S_C}{C_д} \bullet 100$$

S_m and S_C of the above mentioned formulas are the average values of thickness and content (m_{cp} and C_{cp}) and is the value of the square average deviation of the thickness of the ore units and their content in the profits. The following table shows the maximum possible limitations values of parameters for indicating the complexity of deposits. These values are used for reserve estimation of deposits in Russia.

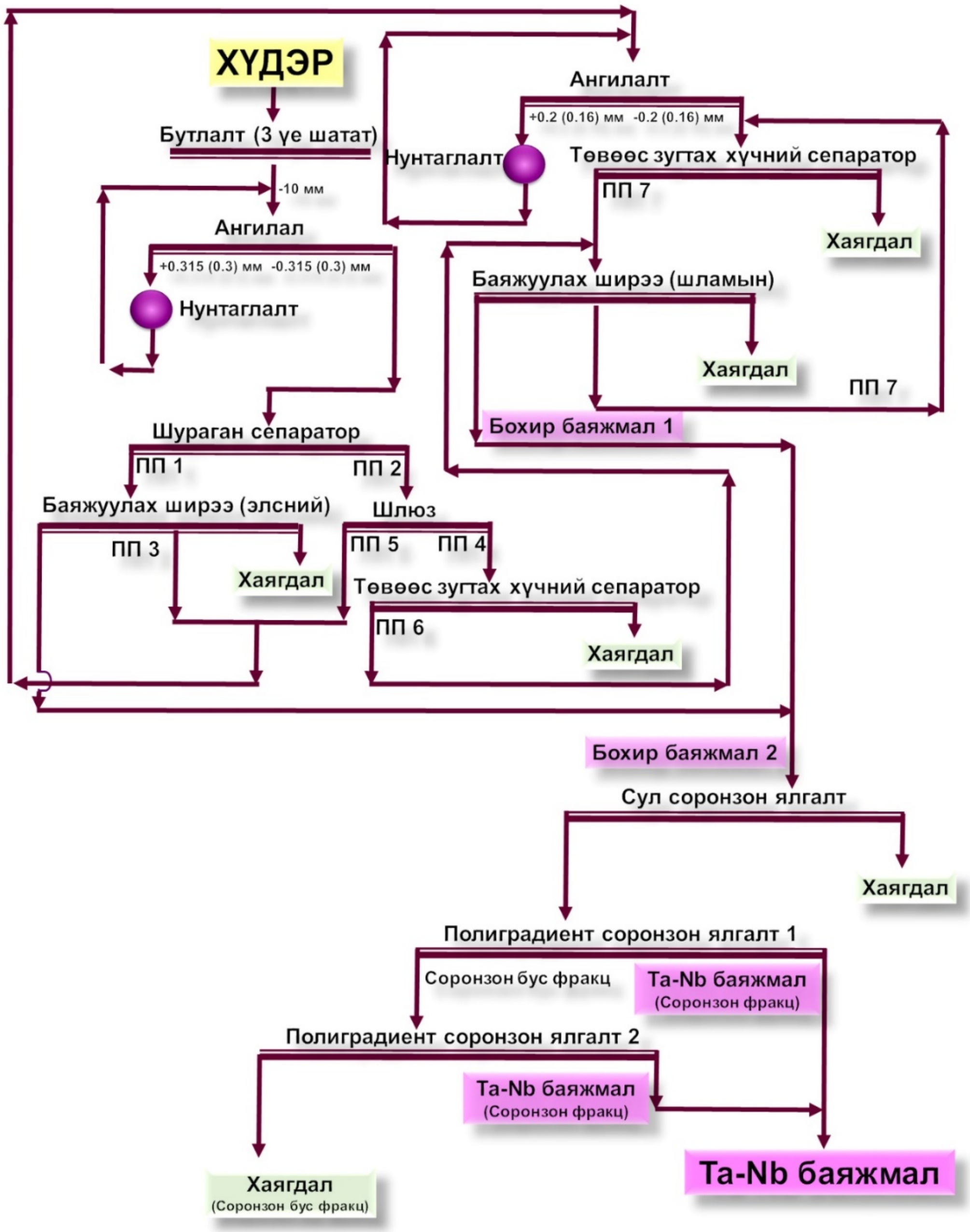
Table.Quantitative characteristics of variability of the basic properties of mineralization

Ore group	Variety parameters for objects under exploration work			
	Morphology of ore body			Content
	$K_р$	q	V_m, %	V_C, %
Group I	0,9–1,0	0,8–0,9	< 40	< 40
Group II	0,7–0,9	0,6–0,8	40–100	40–100
Group III	0,4–0,7	0,4–0,6	100–150	100–150
Group IV	< 0,4	< 0,4	> 150	> 150

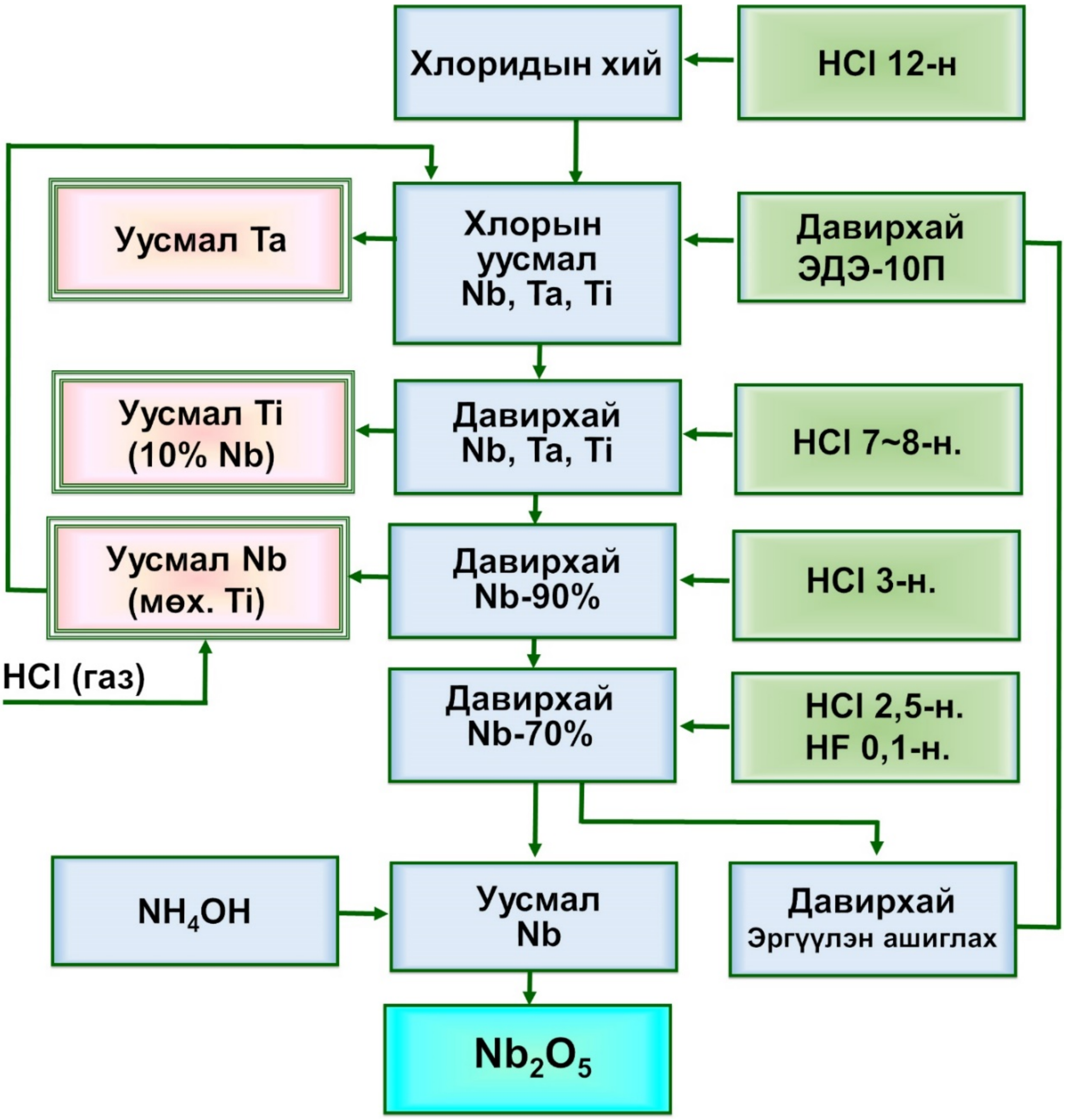
The decision forincluding a certain deposit to a particular group is made based on consideration of the information system of geological all information to express maximum varieties of content of useful component and shape of ore body.

Appendix 2. Technological processing schemes of REE, niobium and tantalum ore

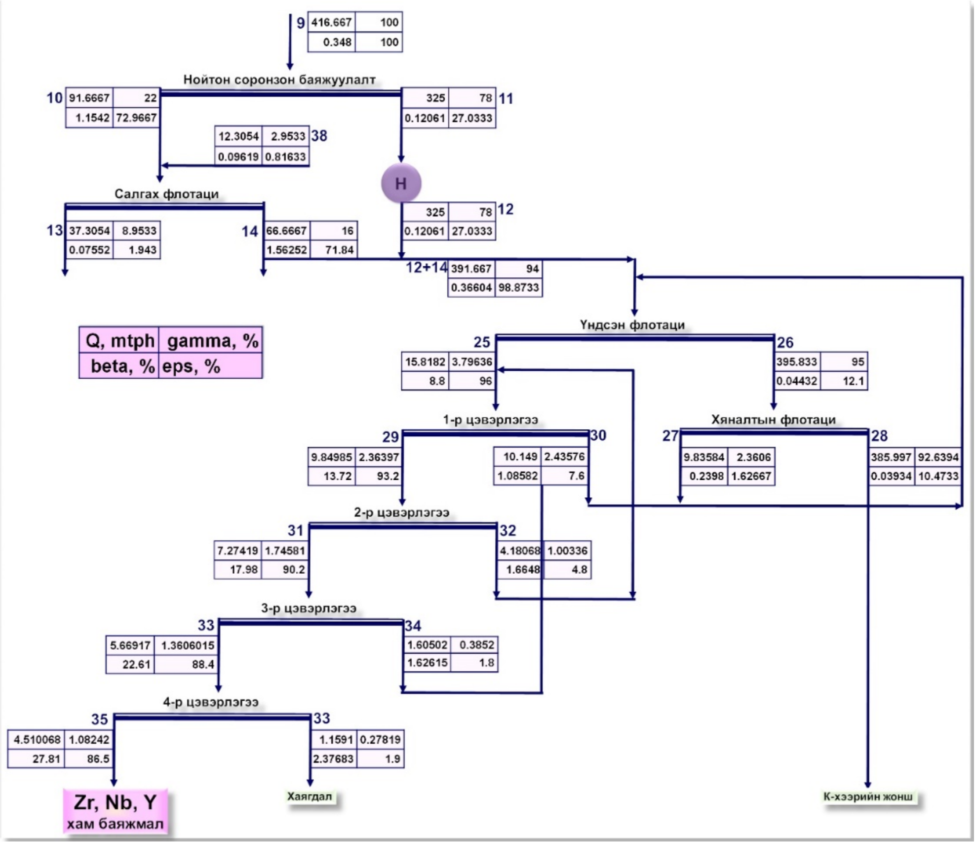
2.1. Gravitation- magnetic separation processing of Tantalum and niobium ore



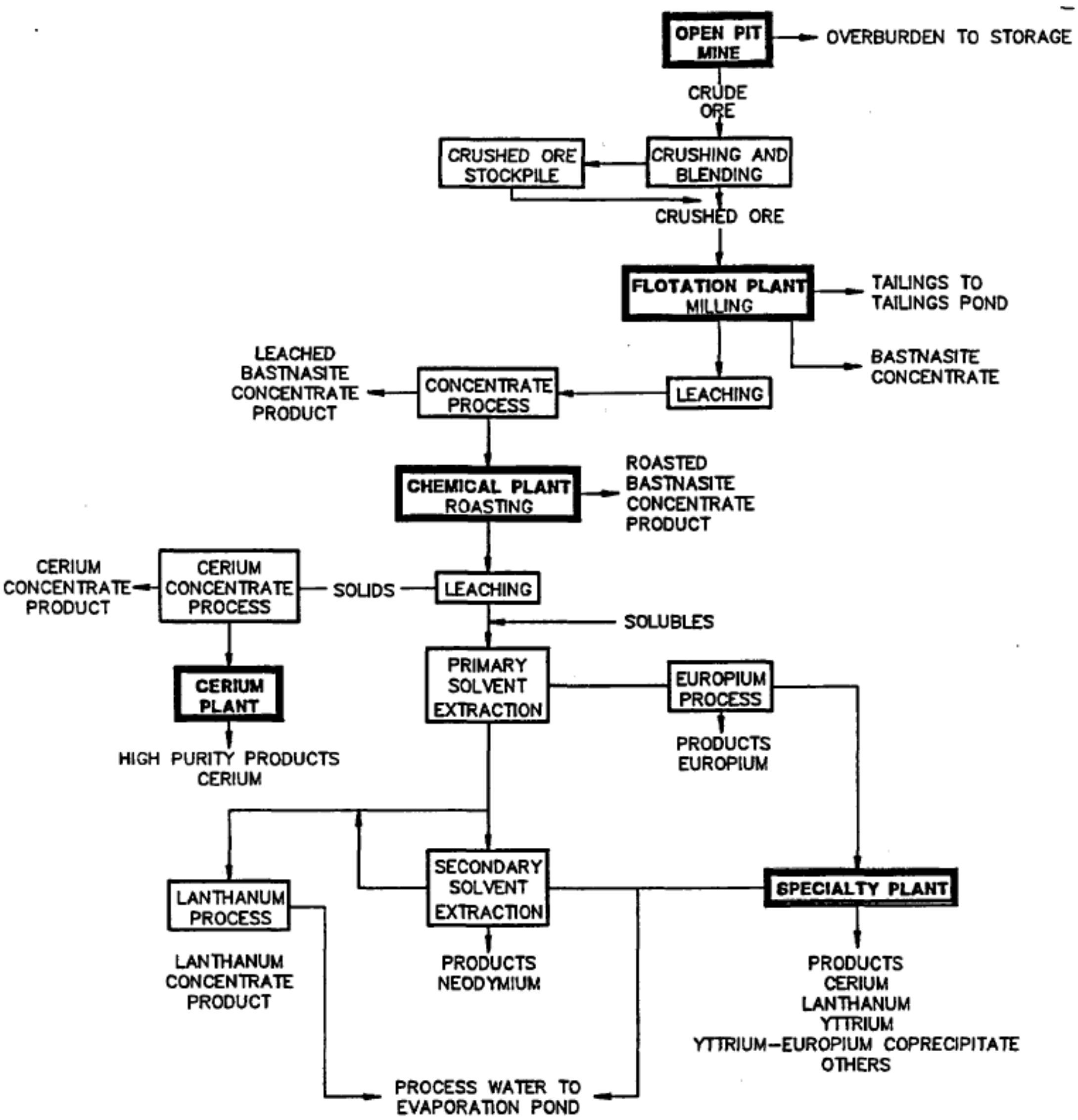
2.2. Technological processing scheme for the separation of niobium and tantalum by ion exchange in an acidic saline solution


Хлоридын хий
HCl 12-н
Уусмал Ta
Хлорын уусмал Nb, Ta, Ti
Давирхай ЭДЭ-10П
Уусмал Ti (10% Nb)
Давирхай Nb, Ta, Ti
HCl 7~8-н.
Уусмал Nb (мөх. Ti)
Давирхай Nb-90%
HCl 3-н.
HCl (газ)
Давирхай Nb-70%
HCl 2,5-н. HF 0,1-н.
NH4OH
Уусмал Nb
Давирхай Эргүүлэн ашиглах
Nb2O5

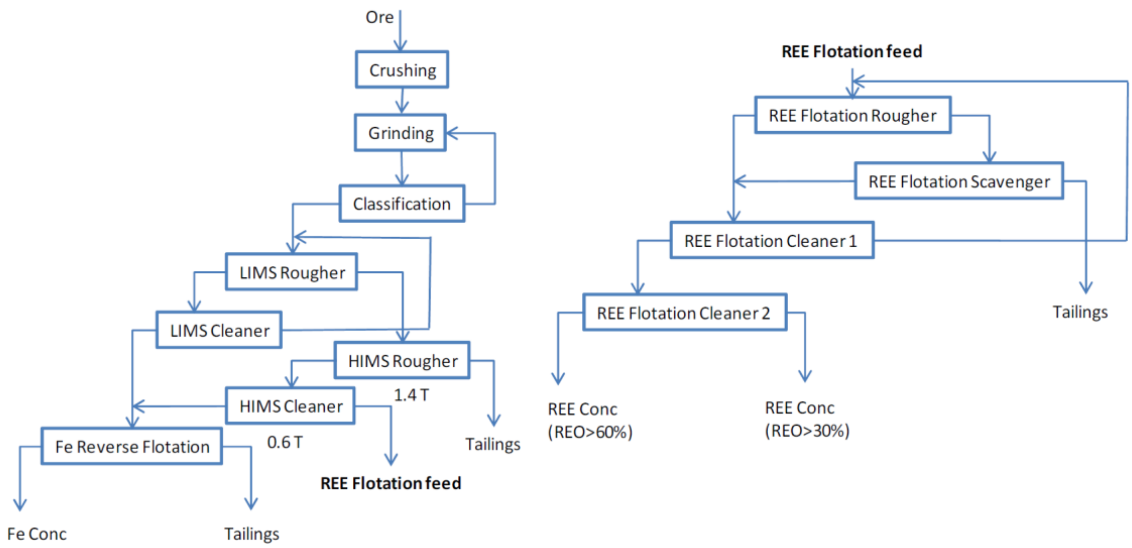
2.3. Technological processing scheme of REE ore, Khalzan burgedei deposit



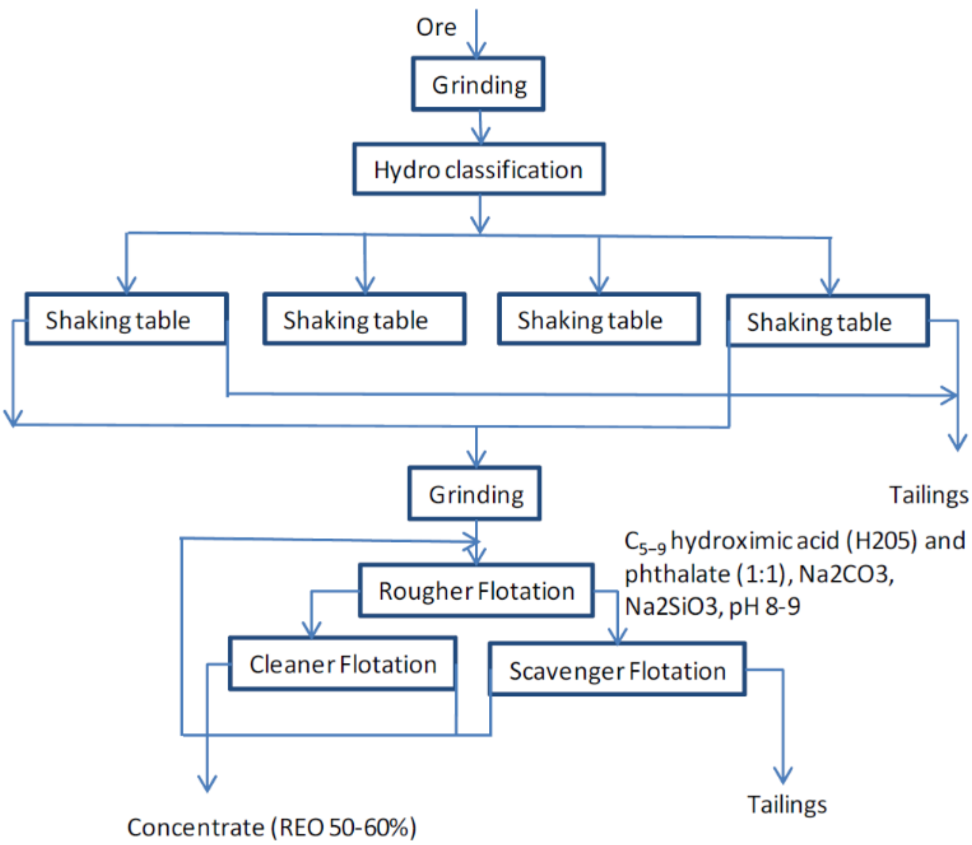
2.4. Technological processing scheme of bastnaesite ore of Mountain Pass deposit



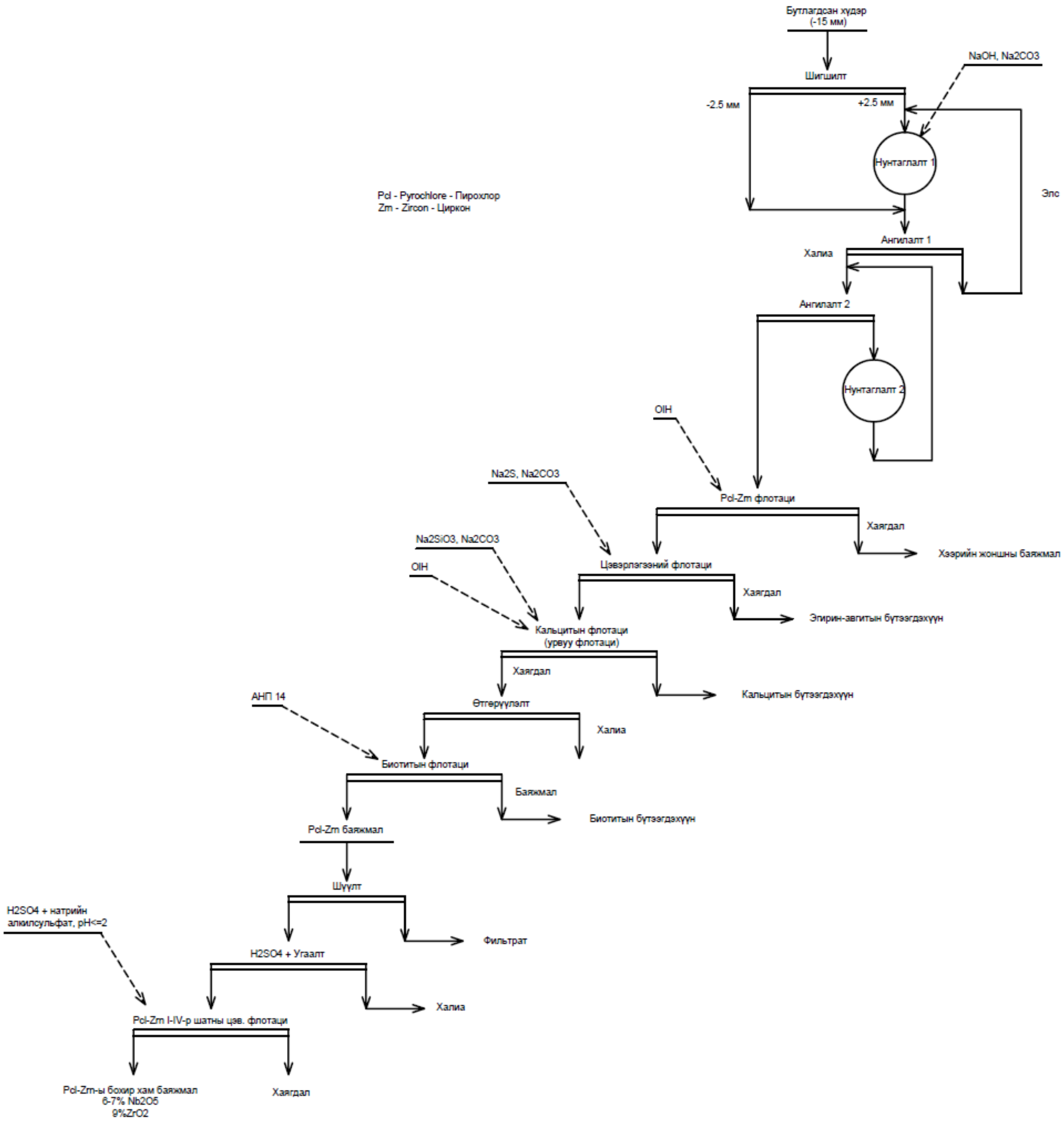
2.5. Technological processing scheme of niobium ore of Bayan-Ovoo deposit



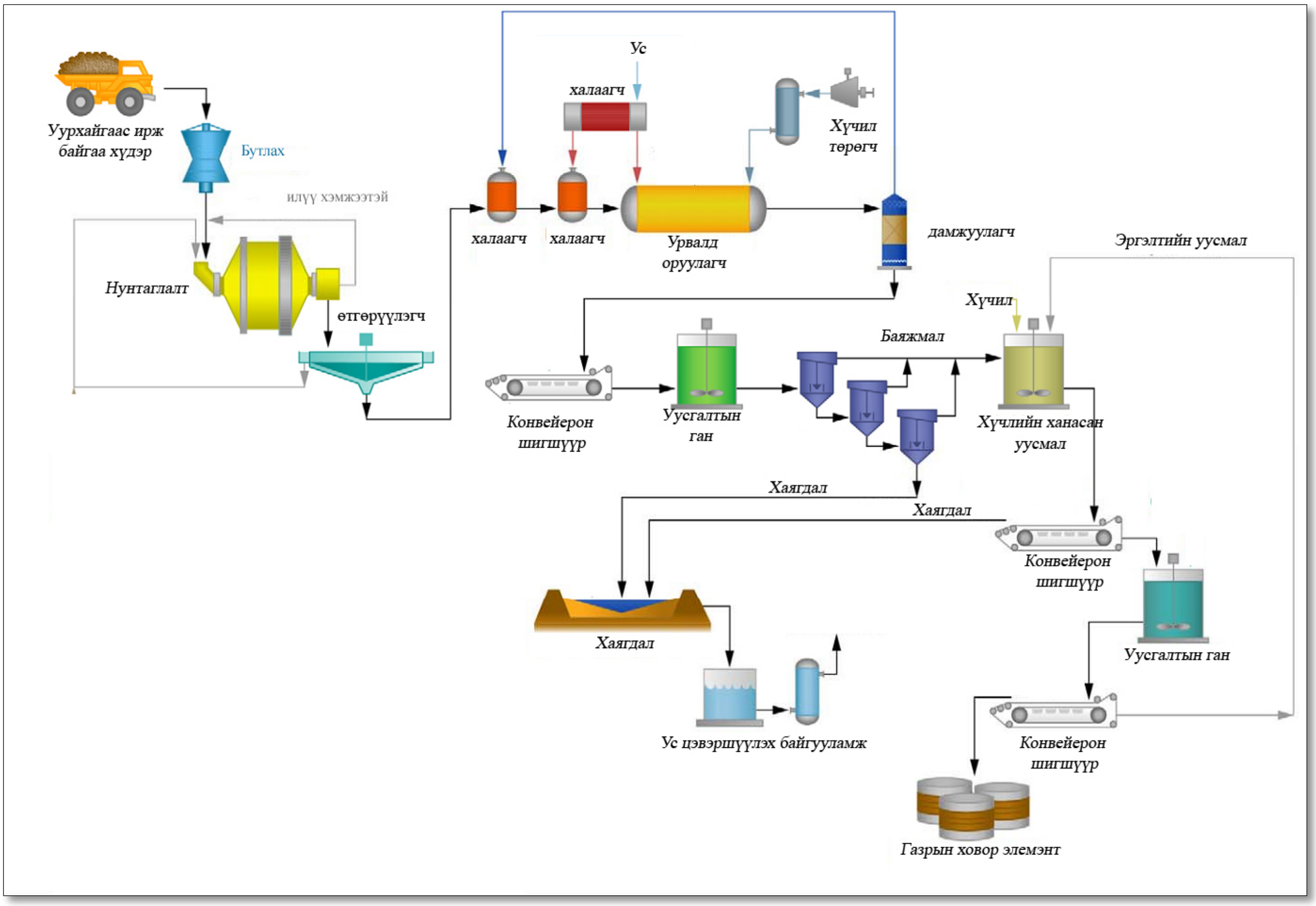
2.6. Technological processing scheme of REE (bastnaesite, chevkinite, parisite, barite, fluorite, iron, manganese) ore of Miannning deposit, China.



2.7. Technological processing scheme of pyrochlore type pegmatite ore in Russia


Бутлагдсан хүдэр
(-15 мм)
Шигшилт
NaOH, Na2CO3
-2.5 мм
+2.5 мм
Нунтаглалт 1
Элс
Pcl - Pyrochlore - Пирохлор
Zrn - Zircon - Циркон
Ангилалт 1
Халиа
Ангилалт 2
Нунтаглалт 2
OIH
Na2S, Na2CO3
Pcl-Zrn флотаци
Хаягдал
Хээрийн жоншны баяжмал
Na2SiO3, Na2CO3
OIH
Цэвэрлэгээний флотаци
Хаягдал
Эгирин-авгитын бүтээгдэхүүн
Кальцитын флотаци
(урвуу флотаци)
Хаягдал
Кальцитын бүтээгдэхүүн
АНП 14
Өтгөрүүлэлт
Халиа
Биотитын флотаци
Баяжмал
Биотитын бүтээгдэхүүн
Pcl-Zrn баяжмал
Шүүлт
Фильтрат
H2SO4 + натрийн
алкилсульфат, pH<=2
H2SO4 + Угаалт
Халиа
Pcl-Zrn I-IV-р шатны цэв. флотаци
Pcl-Zrn-ы бохир хам баяжмал
6-7% Nb2O5
9%ZrO2
Хаягдал

2.8. Scheme of leaching plant of REE ore



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