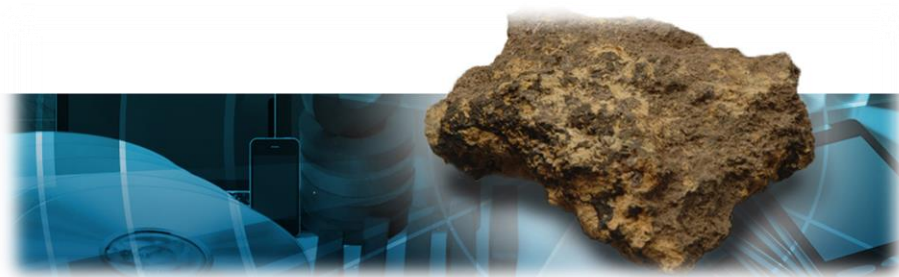


The present work was submitted to the Faculty of Engineering

**Determination of the preparation condition for the rare earth polymetallic ore of
Khalzanburgedei**



Bachelor Thesis

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

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Independently and without undue external help. I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Place, Date

Signature

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Abstract

Rare earth metals are magic. The rare earth elements play key role in the expected growth of many emerging clean energy technologies. The next generation of wind and hydro power turbines, batteries, motors to power electric vehicles and fuel cells are example application. Moreover, the REE used for health, military defence and advanced communications including drug treatments, diagnostic techniques, MRI and visors protection, aircraft parts and GPS ,space based satellites and communication systems. Therefore, the developed countries are mostly used these elements. However, China are restricting rare earths exports to other countries because they are responsible for 97% global output. Therefore, I have chosen rare earth elements topic due to Mongolia has big number of resources and we could export our raw material to developed countries. We have interest to extract rare earth metals and exporting. Therefore, the rare earth metals study is developing in Mongolia.

This study was performed with 2 main goals in mind on the mechanical processing of the Khalzanburgedei polymetallic rare earth mineral ore. The thesis attempt to develop sample preparation of rare earth metals ,sieve analysis and to determine optimum time of grinding in three different P80 value should be carried out and compare with mineralogical analysis result for 125ppm. In addition, focused on charge volume of grinding to get good result.

Rare earth metal sample taken from the Khovd province very near in Myngad soum. Around 80 kg sample were selected to experiment. The sample used to crush, grind and sieve analysis. After grinding the sub samples tested for chemical analysis to determine content of each element in sample.

The results confirmed the rare earth metals is liberated on 125ppm which proved by chemical analysis. A result obtained from the research was compared with the mineralogical analysis. And according to comparison the chemical analysis and mineralogical analysis target are met.

In summary, sample preparation are main procedure of processing that would affect processing result. Coning and quartering method was main method for taking good representative sample. But we need more investigation on this another method is effective than coning and quartering. Another point, the time of grinding depends on ball mill charge includinh water volume, ore mass and ball mass. 25min of grinding is suitable size for reach all minerals are liberate. It is anticipate that this research will lead to a greater understanding of significance of grinding as time for making more small size achieved that have the potential to improve which factors are affecting grinding time optimization.

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Special thanks to Prof.Dr.Battsengel for helping to choose thesis topic and her time, patience and understanding. I am most appreciate to Aachen's research team that their work in Khalzan burgedei deposit project. These people helped me to understand about mineralogy of deposit and how to identify minerals.

My gratitude also goes to the German Mongolian Institute for Resources and Technology processing laboratory, there are not enough words to describe GMIT's lab workers. During my thesis the Baasandorj, Yaruunaa and Munkhjargal who are responsible for lab equipment and they ordered necessary equipment for my experiment.

The most special thanks goes to my best partners, my family members and friends. Class of 2018, you guys gave me your unconditional support and always push me very difficult ways. Thanks for all your love and attentions.

Background

Rare earth elements are (REE) most important raw materials for the new technology development. The resources of the REEs in Mongolia was estimated ca. 1.26mln. tones Khalzanburgedei is one of the important deposit is not yet exploit. The sustainable mining and processing of the Khalzanburgedei deposit has significant importance for economic development of the country.

Obejctive of this experimental task of the thesis is first to take a representative sampling of the ore and crushing to suitable size for sieve analysis. Moreover, to determine optimum time of grinding in two different P80 values should be carried out and compare with the mineralogical analysis result .Finally I evaluates the experiment results and develop and optimum condition for the preperation of Khalzanburgedei ore.

Introduction of rare earth element

The Rare Earth elements consisting of fifteen metals of lanthanide series such as Lanthanum(La), Cerium(Ce), Praseodymium(Pr), Samarium(Sm), Holmium(Ho), Europium(Eu), Dysprosium(Dy), Erbium(Er), Gadolinium(Gd), Lutetium(Lu), Neodymium(Nd), Promethium(Pm), Ytterbium(Yb), and Thulium(Tm), coupled with the chemically similar yttrium, and occasionally scandium (1). These elements can be classified into six classes based on the arrangement of anionic groups such as phosphate minerals monazite and xenotime, carbonate minerals bastnaesite and parisite and silicate minerals allanite (2). Meanwhile, some minerals especially, Nb-mineral pyrochlore could include substantial amount of REEs. However, three most common Rare Earth minerals mined are monazite, bastnaesite and xenotime (3).

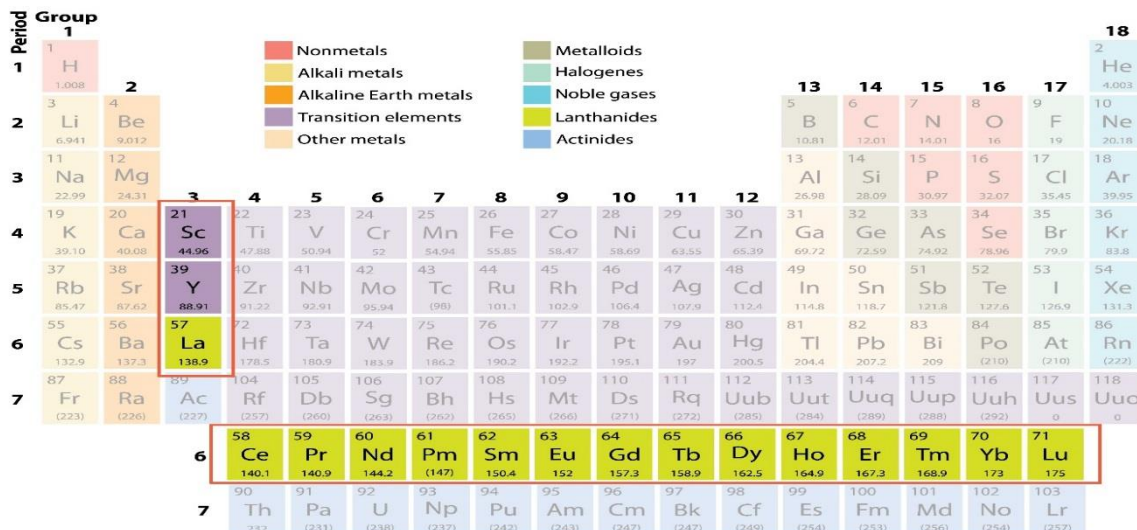


Figure 0-1 Periodic table and rare earth elements with Scandium and Yttrium

REE are never found like a free metals in the Earth's crust and pure minerals of single rare earths do not exist. They are found like an oxides which have proved to be mostly difficult to separate from each other. The rare part of their name refers to the difficulty in finding the pure elements, and not to their relative abundances in the Earth's crust all of the rare earth elements are really more abundant than silver, and more rich than lead (4).

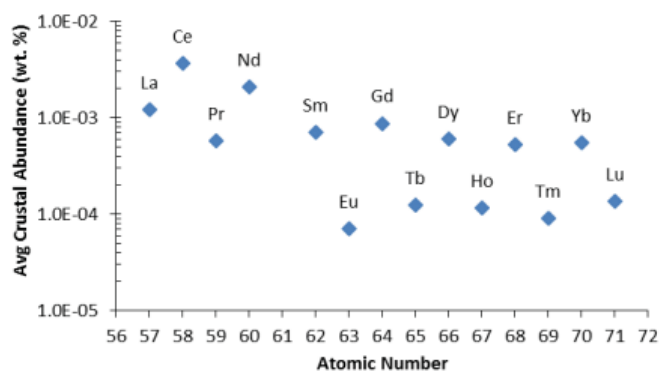
The rare earth elements ore containing REE minerals of carbonates, oxides and silicates and other REE bearing mineral such as zircon and pyrochlore are separated by flotation, leaching and high magnetic separation. Currently, flotation is still most important separation process used to recover monazite, xenotime parisite and other RE minerals in the world by using different hydroxamic acids and fatty acids as the collectors (5).

1.1 Geological distribution

Rare earth elements have come to be of increasing interest given their use in wide array of modern technologies. Therefore, researchers are looking for concentrations of rare earth element that might be economic interest. Also they are investigating minerals in which they occur and how easily element can be extracted. On the other hand, the difficulty in rare earth mineral exploitation is that the rare earth minerals are not commonly found in economic concentration. Rare earth elements never found as pure metals, instead they are found in oxides carbonates, phosphates and halides. There are more than 250 rare earth minerals that have been discovered until now, many of them containing very low concentrations of REE range between 10 to 300ppm (6). REE are found principally in carbonatites. These are igneous rocks comprising more than 50% carbonate minerals, generally calcite (calcium carbonate) but in some cases magnesium-bearing carbonates (dolomite, magnesite) or iron-bearing carbonates (siderite), that crystallised from a high-temperature liquid from deep in the Earth. Carbonatites totally always contain REE, which constitute about 3,500 ppm of these rocks, so they are the most obvious place to look for REE (7). They are found in high concentrations in some, but not all, alkaline igneous rocks (which make up only about 0.5% of all igneous rocks). They are characterised by their high contents of alkali metals.

There are two types of rare earth metals such LREE and HREE. The light rare earth metals consists of (La, Ce, Pr, Nd, Pm, Sm, Eu, Gd) and rest of the rare earth metals are heavy rare earth elements (8). There are also some most abundance elements. The 25th most abundant element in Earth's crust is Cerium, 68 parts per million (about as common as copper) (9). For example, in bastnäsite-(Ce), cerium is present in the largest quantity (it also contains significant amounts of lanthanum, neodymium and praseodymium). Bastnäsite-(Ce) is the most common but bastnäsite-(La) and bastnäsite-(Nd) also occur. The most important rare earth minerals in ore deposits are bastnäsite and monazite-(Ce) (CePO₄). Each contains about 70% rare

Figure 1-2 Rare earth elements atomic number versus average crustal abundance



earth oxides by weight (10).

Other significant ones are the carbonates parisite-(Ce) and synchysite-(Ce) (often found intergrown with bastnäsite), and the phosphate xenotime-(Y). The Figure 1-2 shows us atomic number of rare earths which are different average crystal

abundance in earth crust. For example the Cerium is most abundant than other rare earth elements. Only the Europium is lowest abundance in earth crust.

1.2 Properties of the rare earth metal

The rare earth elements have almost same chemical and physical properties. These metals are quiet similar each other especially the lanthanides. The rare earth elements separations are difficult to achieve due to they occur together in nature. However, there are some much differences, especially in the physical properties of the pure metallic elements. Rare earth elements are divided into three groups such as light rare earth elements (LREE), Middle rare earth elements and heavy rare earth elements (HREE). These elements classified by atomic

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Light REE (LREE), Cerium group								Heavy REE (HRRE), Yttrium group						
LREE					MREE					HREE				

Table 1 Classification of rare earth elements

number which could express the elements heavy or light (11).

Lanthanide contraction

The rare earths are divided into the lanthanide group, and the elements scandium and yttrium. The lanthanide contraction is steady decrease in the values of the radii of M^{3+} cations in the lanthanide series (12). (Figure 1-3) This phenomenon is the important and progressive decrease in atomic radii and in radii of ions when going from lower to higher atomic numbers in the lanthanide series. Thus lanthanum has the largest atomic radius, and lutetium has the smallest (13).

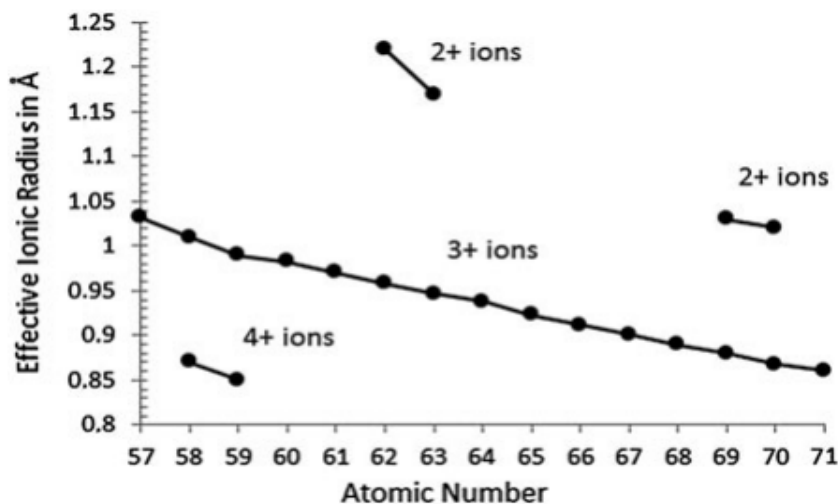


Figure 1-3 Effective Ionic Radius in Å versus Atomic number

Electrical properties

Rare earth metals, the elastic moduli of the rare-earth metals fall in the middle percentile of the other metallic elements. The values for scandium (Sc) and yttrium (Y) are about the same as those of the end members of the lanthanides (erbium to lutetium). There is a general increase in elastic modulus with increasing atomic number. The anomalous values for cerium (some 4f bonding), and ytterbium (divalency) are evident (11).

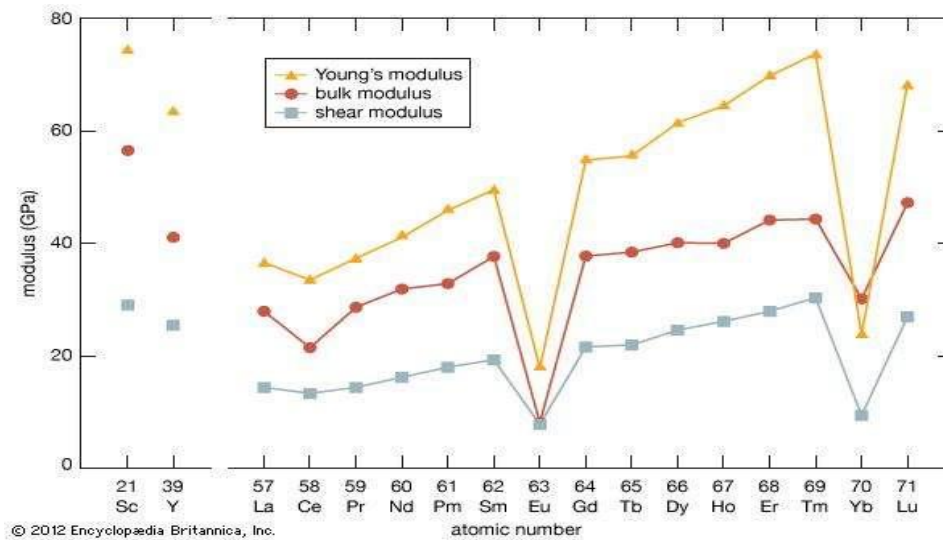


Figure 0-4 Different modulus of rare earth elements

Magnetic and Chemical properties

The main properties which are considered for rare earth elements are magnetic properties, which discusses the ferromagnetism and anti-ferromagnetism. In addition to magnetic susceptibility there are other properties like Galvano-magnetic and magneto-elastic properties are also studied for rare earth metals (14). The rare-earth metals are neither weak nor especially strong metallic elements, and they do exhibit some modest ductility. Because of the mechanical properties are quite strongly dependent on the purity of the metals and their thermal history. The greatest strength varies from 120 to 160 MPa and ductility from 15 to 35 percent. The strength of ytterbium (europium has not been measured) is much smaller, 58 MPa, and the ductility is higher, about 45 percent, as would be expected for the divalent metal (15).

Chemical properties of rare earth elements including density, melting point, boiling point and electron configuration. You can see the elements chemical properties very same each other such as density of Ce and Pr are same and melting points has little bit difference. However, the density will increase with increasing atomic number.

Chemical element	La	Ce	Pr	Nd	Pm	Sm
Density(g/cm ³)	6.162	6.77	6.7	7.01	7.26	7.52
Melting point (°C)	920	795	935	1024	1042	1072
Boiling point (°C)	3464	3443	3620	3074	3000	1794
Atomic electron configuration (solid phase)	$5d^1$	$4f^15d^1$	$4f^25d^1$	$4f^35d^1$	$4f^45d^1$	$4f^55d^1$
Metallic radius (pm)	162	181.8	182.4	181.4	183.4	180.4

Table 0-1 Chemical properties of some lanthanide group elements

Typical rare earth properties

- The rare earths are silver or gray metals
- The metal have a high luster
- The rare earth have high electrical conductivity
- There are very small differences in solubility and complex formation between the rare earths.
- The rare earth metals naturally occur together in minerals (monazite is a mixed rare earth phosphate.)
- Relatively soft metals. Hardness increases somewhat with higher atomic number.
- Moving from left to right across the period (increasing atomic number), the radius of each lanthanide 3^+ ion steadily decreases. This is referred to as 'lanthanide contraction'.
- High melting points and boiling points
- Very reactive.
- React with water to liberate hydrogen (H_2), slowly in cold/quickly upon heating. Lanthanides commonly bind to water.
- React with H^+ (dilute acid) to release H_2 (rapidly at room temperature).
- React in an exothermic reaction with H_2 .
- Burn easily in air.
- They are strong reducing agents.
- Their compounds are generally ionic.
- At elevated temperatures, many rare earths ignite and burn vigorously.
- Most rare earth compounds are strongly paramagnetic.
- Many rare earth compounds fluoresce strongly under ultraviolet light.
- Lanthanide ions tend to be pale colors, resulting from weak, narrow, forbidden $f \rightarrow f$ optical transitions.
- The magnetic moments of the lanthanide and iron ions oppose each other (16).

- The lanthanides react readily with most nonmetals and form binaries on heating with most nonmetals.

1.3 Major ore minerals

There are three types of major ore elements and thus elements are still exploited nowadays.

1.3.1 Monazite

Monazite is phosphate mineral with rare earth content approximately 70% rare earth oxide (CePO₄). Besides Ce, also other REE occur in monazite. These are mostly the LREEs (Light Rare Earth Elements: La, Ce, Pr, Nd, and Sm).

Monazite usually also contains Th, but the amounts in monazite are generally too low to be extracted as a valuable by-product. Monazite occurs generally as a minor mineral in granites and granodiorites and associated pegmatites, and also occurs in many metamorphic rocks.

Because monazite is a heavy mineral with a specific gravity ranging between 4.8 and 5.5, with an average of 5.15, and very resistant to weathering, it concentrates after weathering of the igneous or metamorphic host rock and subsequent transport in placers and heavy mineral sands (17).

- Monazite-(Ce), (Ce, La, Nd, Th) PO₄ (the most common member)
- 4-12% ThO₂
- Monazite-(La), (La, Ce, Nd) PO₄
- Monazite-(Nd), (Nd, La, Ce)PO₄
- Monazite-(Sm), (Sm, Gd, Ce, Th)PO₄

1.3.2 Xenotime

Xenotime is a yttrium phosphate mineral with a rare earth oxide (YPO₄). Xenotime may contain up to 67% REO, mostly the heavier elements. Xenotime, in contrast to monazite and bastnaesite, generally contains, besides Y, appreciable amounts of the HREE).

Xenotime is an accessory mineral in pegmatites and other (non-basic) igneous rocks, but also is common in metamorphic rocks. Xenotime, being very similar to monazite also has a high specific gravity, in the range 4.4–5.1, with an average of 4.75 and also concentrates in placers and heavy mineral sands. However, such deposits are not widespread (17).

1.3.3 Bastnasite

Bastnasite is fluorocarbonate mineral with a rare earth content of approximately 70% of rare earth oxide that is primarily (Ce, Pr and Nd). Bastnaesite is a widespread mineral, although it

never occurs in large quantities. It occurs in a variety of igneous rocks, such as carbonatites, vein deposits, contact metamorphic rocks, and pegmatites. Major ore deposits are generally related to carbonatite intrusions. Carbonatites are often found in relation to alkaline intrusives. The separation process for bastnaesite ores may employ numerous operations including gravity and magnetic concentration. Also we can use flotation using fatty acid collector system for separation process.

- Bastnaesite-(Ce), $(\text{Ce, La})\text{CO}_3\text{F}$
- Bastnaesite-(La), $(\text{La, Ce})\text{CO}_3\text{F}$
- Bastnaesite-(Y), $(\text{Y, Ce})\text{CO}_3\text{F}$

1.4 World usage , global production

The application and demand of rare earth elements has increasing nowadays due to widely used in high technologies, medical devices, military defense systems, and especially necessary in emerging clean energy.

First Rare earth elements was discovered in 1788. Until 1948 most of them sourced from place sand deposits. During that period global rare earth production and consumption was less than 5000 metric tons of REO. Since the 1960s, rare earth rarely used in our daily life and applications regularly have increased to everyday life such as television screens, the petroleum industry, and computer systems (18).

Currently, There are two major producing REE country thus, are China (produced 81% of the world rare earth supply mostly in Bayan Obo deposit) and Australia(it is second producer and 15% of world production). The total 478 megaton rare earth oxides are registered in 2017. There are 178 deposits which are broadly spread in 58% of these deposit contained more than 0.1 Mt REO and 59 deposits have been technically assessed in the world (18) .

Rare earth elements application:

Terbium (Tb)– Green phosphors, lasers and fluorescent lamps

Dysprosium (Dy)- Magents lasers

Holmium (Ho)- Lasers

Erbium (Er)- Lasers (for communications), vanadium steels

Thulium (Tm)- Electron beam tubes, medical imaging system (X-ray detection)

Ytterbium (Yb)- Infrared lasers, electrical stress gauges, reducing agent

Lutetium (Lu)- Scintillation counters

Yttrium (Y)- Automobile use, microwave communications, lasers

Lanthanum (La)- Petroleum refining, high-index glass,flints, hydrogen storage,battery electrodes

Cerium(Ce)- Catalytic convertors, oxidizing agents,polishing powders,yellow glass/ceramics,catalysts in self cleaning ovens

Praseodymium (Pr)- Magnets, lasers, green glass/ceramics,flints,pollution control

Neodymium(Nd)-Magnets, lasers,

Samarium(Sm)-Magnets,lasers neutron capture,masers

Europium(Eu)-Red/blue phosphors,lasers fluorescent lamps, mercury vapour lamps

Gadolinium (Gd)-Magnets,high index galss,lasers,X-ray tubes,computers memory,neutron capture (19).

1.5 Recycling

The recycling of Rare Earth element actual limited in the world and only less than 1-2% of all REE recycled (20).

Rare earth reusing industry is developing with some activites still at development stages. Nowadays, the Rare earth demand is rapidly increasing due to using high technology and China is restricitng export rare earth metal. Because of China is exporting more than 90 percent rare earth metals to the world that is they can define price and how much raw material export to the another country. Another countries do not want to depend on chinese decision. Therefore, they are always looking new way to have rare earth metals. There are some options such as recycling and exploring rare earth metals. But exploting way is too diffucult due to they have not any deposit of rare earth. For recycling, There are reusing options, however the options must be several advantages including lower environmental impact, less dependancy of chinese export and feed materials can be free from radioactive contaminants such as (Th and U). As I mentioned in major ore minerals which including 3 main minerlas consisting monazite,batsanite and xenotime. All of them minerals has Th and U containts which are the radioactive that means difficult to reuse.

Rare earth elements have an important role in permanent magnets, lamp phosphors, rechargeable batteries, catalysits and other application. That means, there are some possivle opportunities available for recycling of rare earths are typically from used **magnets, batteries, lighting**(compact fluorescent lamp, LED, plasma display,LCD display) and **spent catalysts**(in automobile and petroleum refining). The materials could be sourced from wastes and consumer disposed goods (21).

Recycling sources:

- Direct recycling of metal scrap and swarf which is formed during the production of metal based final or intermediate products (for instance NdFeB-magnets – Neodymium iron boron).
- Postconsumer materials (recycling and urban mining): complex, multi material, metal containing products (for example hybrid electric vehicles (Fig 1-3 and 1-4)).
- Lanfill mining of historic urban solid waste.
- Metal recovery from stocks of landfilled industrial process residues (22).

Currently, more attention is focused on direct recycling of scrap due to end of life REE containing product. The most interesting end of life products are permanent magnets, lamp phosphors, flat screen phosphors and rechargeable batteries (Ni-metal hybrid batteries).

Permanent magnets is Neodymium iron boron (NdFeB) which is higher energy product (with a theorotical maximum of $512\text{KJ}/\text{m}^3$), that makes permanent magnets highly efficient and suitable for lightweight mobile application (23). It generally used in wind turbines, computer hard disk drives and samll consumer electronic devices. End of life times are different each other for example, wind tubines are 20-30years and consumer electronics are 2-3 years short. Furthermore, The wind turbine generators and (hybrid and electronic vehicles) consists of 1000-2000kg and 1kg magnets. NdFeB magnets contains range between 31-32 weight percent rare earth elements, mainly Nd+Pr and expensive heavy rare earth such as Dy,Tb depending on applications (24).



Figure 0-3 Recycling from hybrid electric vehicles



Figure 0-2 Recycling from electronics

2 REE in Mongolia

Mongolia is rich in rare earth occurrences of very small to small sizes and low grade, only three deposit such as Khalzanburgedei, Mushgai Khudag and Lugiin Gol are potential profitable interest.

2.1 Lugiin gol of dornogovi

The Lugiin Gol rare earth deposit (centre at 42° 57' 46" N; 108° 35' 12" E, 1080 m) is located in Hatanbulag Soum of Dornogovi province. It lies 58km north of the Mongolian Chinese border and 175km north-west of the world famous and giant Bayan Ovoo rare earth deposit in northern China. The Hatanbulag Soum centre is 60km away from the deposit. Within the boundaries of the Lugiin gol massif, a first carbonatitic vein was discovered in 1971 by Russian geoscientists. From 1984 to 1987, a joint Mongolian-Polish geological expedition carried out an extensive exploration campaign for these carbonatites, which was followed by even more exploration work until 1989 and many visits by interested stakeholders, mainly from Japan, in the years thereafter. The most recent exploration campaign took place from 2005-2009.

The Lugiin Gol massif consists of the Lugiin gol nepheline syenite complex of Lower Triassic age (50%), a 300 to 1300m wide contact zone made out of hornfelsed shale (35%) and surrounding host rock, which is black shale of the lower Permian Lugiin gol Formation 15%. The massif forms a pseudocaldera with an almost circular structure and eroded surface.

The Lugiin gol nepheline syenite complex consists of a nepheline syenite stock and equivalent dike rocks. The stock crops out in an area of approximately 12km², and has a circular outline with a diameter of 3.5km. The stock is composed of nepheline-bearing syenite, alkali nepheline syenite and nepheline-bearing melasynites. Similarly a vast variety of different rock types were encountered in drill cores. The dikes are attributed to two stages pre dikes and post dikes.

The Lugiin Gol complex is consisted of hundred of mineralised veins and dikes. According to findings of the most recently the total resources amount to 505822tonnes of ore grading 2.67% rare earth on average.

2.2 Mushgai hudag of Umnugovi

The Mushgai Khudag rare earth deposit (Khuren khad ore zone). It is high grade zone was discovered in 1975, prospected in 1983 and 1984 also explored in more detail between 1989 and 1994. The most recent exploration campaign took place between 2007 and 2009. The deposit is located in Mandal Ovoo soum of Umnugovi province. It is far away 32km south west of Mandal ovoo village and 100km north of Dalanzadgad soum.

The deposit of rare earths enriched carbonatite lies on the western part of the prominent Mushgai uplift and is surrounded by sedimentary and volcanogenic rocks of Silurian to Devonian age. The Mushgai Khudag volcanic plutonic complex forms a ring structure of 27km in diameter and consists of Late Jurassic alkaline rocks composed of syenites, granisyenote porphyries and shonkinite porphyries, which form small bodies, dikes and stocks from several tens of meter square to 1 meter square in size. Controlled by north east, sublatitudinal and north west trending faults, the mineralisation is dominated by P, Ba, Sr, Ree, and Fe and genetically related to the syenite intrusions.

At least 17 different ore bodies, spaced 100-1200m apart, of various shapes, structures, and composition are known. In particular:

- Steeply dipping lenticular and pillar like pipes 900m in extent and 200m thick
- Stock-like and irregularly shaped bodies 10-30m x 20-70 m in size
- Stockworks up to 30x200 m size

In general, four types of mineralisation can be distinguished:

1. Mineralized breccia with carbonate cement
2. Mineralized carbonatite
3. Magnetite-apatite ore
4. Apatite ore

Apatite-bastnaesite carbonatite ore and apatite ore are the most important ores, as they are most enriched in rare earths.

Apatite-bastnaesite carbonatite ore appears in two different types, such as in the form of veins and in the form of mineralized breccias. Both types consist of calcite and dolomite (50%), celestite and barite (up to 10-15%), fluorite (up to 10%) apatite, and wide range of rare earth minerals.

- There are four different ore zones:
- Tumurtei ore zone
- Khuren Khad ore zone
- Main ore zone
- A newly discovered High grade ore zone

The average Rare earth grade in Mushgai Khudag is 1.36% and even reaches 6.15% in the average in the newly discovered high grade ore zone. The total rare earth oxide content is 436617 tonnes.

2.3 Khalzanburgedei of Khovd

The Khalzan Burged rare earths and rare metals deposit located in Khovd province and main deposit far away 45km north west Khovd city. The deposit was discovered in 1983 and explored in detail in the years thereafter. It is part of the lake zone of western Mongolia, which contains several rare earth metals deposits of middle Devonian age.

Exploration History:

- 1983-Discovered by a soviet Mongolian expedition in 1983
- 1991-By the request of Mongolian Government, the Russian geologists conducted further studies in 1991 including geomagnetic mapping, prospecting, drilling geochemical investigation, trenching and sampling
- 2008-Based on verification of the plausibility of old documents, further exploration was conducted from 2008 to 2009 by G.U.B. Ingenieur mineralogical-geochemical investigation, block modeling of the deposit with GEMCOM SURPAC, estimation of resources etc.
- 2011-2012 Mongolian Lanthanide Corporation LLC conducted total 16 boreholes and 4570.3 m core drilling program on the deposit with the average depth of 284 m
- 2015 to- German researchers are investigating the deposit geology and doing mineral processing work



Figure 2-1 Map of the Khalzan Burgedei REE-Zr-Nb deposit

The khalzand burgedei deposit has been known as REE (La-Lu)-Zr(zirconium)-Nb(niobium) deposit and is studied the most HREE rich deposit in Mongolia due to other REE deposits in Mongolia are normally rich in LREE.

2.3.1 Deposit geology and mineralization

Khalzan Burgedei is rare earth elements deposit which is part of the plutonic massif of the same name occurring within Tsagan-Shilbetein fault zone which separates the lake zone in the west from structural zones of the Mongolian Altai. It consists of rare earth metals, peralkaline granites, pantellerites and cemendites (peralkaline rhyolite) and albitic nepheline syenites.

According to the geological exploration results, mineralized alkaline granites intruded into barren nordmarkites and were thus affected by extensive metasomatic overprinting linked to mineralisation by rare earths and rare metals. Important for this mineralisation is the **quartz-albite** metasomatism of the alkaline granites.

Mineralization is to the north and east of the ore body which bounded by two main fault systems and in the south and southwest by a pegmatite seam. The size of the ore body is approximately 800 meters. The peralkaline granite syenite plutons show Zr-Y-Nb-REE mineralization for which magmatic enrichment and hydrothermal concentration of rare earth metals and earth elements are found, among other places in mineral zircon, bastnasite, monazite, pyrochlore, synchysite and xenotime.

REE-Zr-Nb mineralization is recognised in granite and that the high grade zone is located in the south of granite area. The granite is peralkaline granite consisting of quartz, plagioclase (mostly albite), K-feldspar, alkali amphibole (arfvedsonite) and accessory minerals, characterized by coarse grained granular euhedral quartz phenocryst. The granite generally shows the high radiation dose rate, high REE-Zr-Nb contents and low magnetic susceptibility.

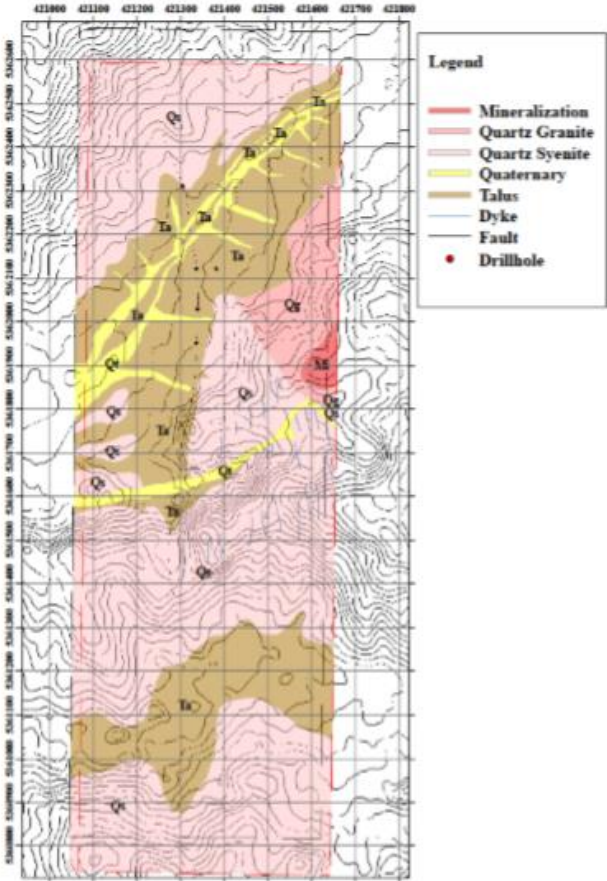


Figure 2-2 Map of the Geology of the Khalzanburgedei deposit

The deposit ore minerals can be classified into three categories: Zr silicates, REE fluorocarbonates, and Nb oxides. Zr silicates consist of elpidite, zircon and gittinsite, and they are HREE+Y bearing minerals as well. REE fluorocarbonates generally occur as aggregates of fine grained crystals in granite. The dominant Nb-oxide is pyrochlore and this grain size is coarser than the other ore minerals.

Grade of REE+Y,Zr and Nb at the surface

Rare earth elements ranges between 95 to 7705 ppm, subdivided into Light REE grade ranging from 80 to 7127 ppm and HREE grades ranging from 15 to 1050 ppm.

2.3.2 Modal composition of ore

The data of modal mineralogy are shown in Table 2-1. A total of 24 mineral were identified MLA (mineral liberation analysis) which investigated in Germany. Taking mass percentage, The silicates are almost 89 %, carbonates take up 1.25 % and oxides and other minerals are 8.55 % in mass. The identified REE minerals and REE bearing minerals are parisite, synchysite(Y), pyrochlore and zircon. The REE are divided into 3 categories not only carbonate and oxides. There are silicate minerals mostly in rare earth. The silicate minerals (albite, Britholite, Titanite). Light REE s are mainly contained in carbonate minerals (parisite), bastnaesite) and silicate mineral (britholite) while and heavy Rare earth elements are mainly contained in Zr silicate mineral (zircon), Nb mineral (pyrochlore – Nb₂O₅) and carbonate mineral (synchysite-Y).

Thus elements liberation size fine to coarse are 10-200µm that based on the mineralogical studies. We could recover the RE carbonates, Zr silicates and pyrochlore minerals by wet high intensity magnetic separation (WHIM)- settling method cause only these mineral include rare earth metal and elements. After using wet high intensity magnetic separation the pyrochlore recover percentage would be 100%. Khalzanburgedei deposit minerals are mostly named complex ore cause it including many types of minerals such as Quartz, Albite, Fluorite, K-feldspar and chlorites. This mean the modal composition of ore include many other elements except rare earth elements (25).

You can see modal ore composition of khalzanburgedei deposit from Table 2-1.

Silicate	wt%	Carbonate	wt%	Oxide and other	wt%
K-feldspar	22.96	Parisite	0.13	Fluorite	3.38
Albite	30.11	Bastnasite	0.09	Rutile	0.22
Quartz	30.23	Synchysite	0.3	Hematite	2.26
Zircon	3.97	Monazite(PO ₄)	0.03	Ilmenite	0.29
Willemite	0.04	Carbonate	0.74	Pyrochlore	0.52
Titanite	0.12			Chlorite	0.07
Britholite				Muscovite	0.02
Arfvedsonite	2.31			Unclassified	1.79

Table 2-1 Classification of modal composition

3 Literature review for unit beneficiation operation

Currently the separation processes are improving day by day. Rare earth elements are very difficult to separate from the other minerals due to their almost same chemical and physical properties. The principle separation processes active in beneficiation of rare earth minerals include gravity separation, magnetic separation, electrostatic separation, froth flotation and leaching which is a chemical separation process.

3.1 Gravity separation

Gravity separation depends on the differences in density of minerals to provide efficient separation. Rare earth minerals are good candidates for gravity separation due to they have large specific gravities 4 to 7. Because the valuable minerals in the sample, except for elpidite, have high densities therefore gravity separation is a potential method to recover them. The most generally used application of gravity separation is in monazite beneficiation from heavy mineral sands. At this point, the separation process depends on each individual deposit's mineralogy.

In addition to the processing of beach sands, gravity separation (shaking tables, spiral concentrators, and conical separators) is used in combination with froth flotation at many Rare earth metal processing operations throughout China. An example, Bayan obo deposit very similar to the Khalzan Burgedei deposit because these deposits are polymetallic complex deposits. The gravity separation has been used between rougher and cleaner flotation circuits to separate monazite and bastnaesite from the iron bearing and silicate gangue minerals in the Bayan Obo deposit. In this case we would follow this separation process in the Khalzan Burgedei deposit separation of rare earth.

A final interesting application of gravity separation to Rare earth metal concentration is the use of roasting operations prior to gravity separation. The idea presented involved roasting a rare earth carbonate ore at temperatures in excess of 1000 °C to convert the carbonates into oxides, thereby increasing the mineral density and susceptibility to gravity separation (26). The process included an industrial application involving quenching the roasted ore particles from high temperatures; a process that would likely significantly decrease the energy required for crushing and grinding operations in their research into thermally assisted liberation.

3.2 Magnetic separation

Magnetic separation is a process used to separate materials (rare earth metals) from nonmagnetics. The separation techniques are a common separation step in rare earth mineral beneficiation to remove high magnetic gangue or to concentrate wanted paramagnetic (hematite) REE bearing minerals such as monazite and xenotime. From the

electron magnetic configuration, the rare earth elements generally have a series of electrons occupying a shielded 4f sub-shell and these electrons characteristically have magnetic. Most M^{3+} lanthanide ions has magnetic susceptibilities which based on their chemical composition

The khalzanburgedei deposit consists of quartz(SiO_2), K-feldspar($KAlSi_3O_8$ hematite, pyrochlore, Bastnasite-Ce, Parisite-Ce, Synchysite-Y and zircon. (27). At this point, some of them has magentic propties such as hematite, chlorite Arfvedsonite thus are strongly magnetic and Bastnasite-Ce, Parisite-Ce, Synchisite-Y which are normal magnetics (28).

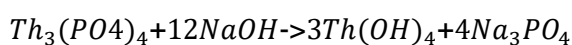
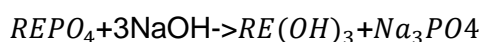
3.3 Froth flotation

Froth flotation is most widely used method for ore beneficiation and is a physico chemical seperation process which based on difference in surface propties of the valuable minerals (29). Rare earth minerals that bastnasite and pyrochlore are usually seperated by flotation especially when their liberation sizes are fine. Due to fine liberation size of the majority of the valuable mineral in sample, flotation was applied to recover them (6).

Currently, The flotation is most used beneficiation method used to recover rare earth metals such as bastnasite, monazite ,xenotime and othe RE minerlas in the world by using different good collectors such as hydroxamic acids and fatty acids. In flotation the collectors are main important factors. Therefore, choosing collectors are still main problem for recover rare earth mineral (30). Flotation always conducted with surface propties such as hydrophobic and hydrophilic propties . Thus, surface propties are main player of the flotation principle. If investigating flotation test we should focus on suitable collector in the rougher stage, then optimized the resiltis by changing the conditions such as effect of no desliming, collector concentration ,regular concentration, pH and used of scavenger collector.

3.4 Leaching

Leaching is a simple chemical method to evaluate the extractability of elements from the minerals, therefore it is usually first done in evaluating the recovery of desired elements from the ore. For example the monazite is the rare earth phosphate mineral, containing mostly light REE. It can contain up to 70% rare earth elements. In monazite there are three process to leching such as digestion in hot 60-70 % NaOH, Washing residue with how water and leach with some mineral acid of choice. Below main chemical reaction is shown:



Nowadays, main challenging of leaching is the dilution effect of Rare earth elements in contaminants and tailings. Therefore, some advancements recommending such as microwave leaching and bioleaching (31).

4 Experimental Methodology

The thesis work based on sample preparation of rare earth polymetallic deposit in Khalzaburgedei. The sample preparation In this experiment, I did a lot experiments such as taking representative sample, crushing, sieving and grinding samples. The samples taken from the Khalzand burgedei deposit in Khovd province. During taking samples, I fully understood why we need to learn mineralogy course. Because, There was many different stone that should be firstly identified by own knowledge and geological method.

Objective

Objective of this experimental task of the thesis is first to take a representative sampling of the ore and crushing to suitable size for sieve analysis. Moreover, to determine optimum time of grinding in two different P80 values should be carried out and compare with the mineralogical analysis result. Finally I evaluates the experiment results and develop and optimum condition for the preparation of Khalzand burgedei ore.

Mineral processing

The all experiment related to mineral processing which is separating valuable minerals from their ores. For example, In this experiment I have prepared previous process of separating rare earth metals from the ore.

Major process of mineral processings are:

- Size reduction (Crushing and Grinding)
- Size control (Sieving and classification)
- Enrichment (Froth flotation, Magnetic separation, Gravity separation and Leaching)
- Upgrading (Sedimentation and Mechanical dewatering, Thermal drying)
- Materials handling (Feeding, Loading, Conveying and Unloading)
- Slurry handling (Slurry transportation, Agitation and Mixing)
- Wear in operation
- Operation and environment
- Process systems

Processing operations has a 2 types which are dry and wet:

- Dry processing occur when no water is allowed and needed for processing.

- Wet processing occur to get more efficiency which mean no loss material (no dusting).

Mineral processing consists of two fundamental operation that are liberation of the valuable minerals from their waste gangue minerals(comminution) and concentration.

The concentration is seperation of these values from gangue. The experiment tasks are including comminution and sizing process.

Comminution is particle size reduction of material. It could be carried out on either dry material or slurry (wet material). The size reduction reduce sample size to size need for the beneficiation process. Crushing and Grinding are two major method for comminucation process.

Size analysis is the typical name for separation of particles according to their size. In laboratoty, the simplest sizing process is screening. The size begins from 12 mm to 20 μ m. In industry there are many different types of screen thus include grizzlies, bar screen, wedge wire screen,radial sieves, banana screens,vibratory screens and wire mesh screen. They have different operation principle such as shaking and vibrating mechanisms. Also the screen have some consideration to taking good size distribution that are aperture size,shape, frequency of vibration (intensity) and addidtion of water. Main important factor of comminution is determination of the particle size distribution of the materials being processed.



Figure 4-1 The experiment was conducted that place

4.1 Sample preparation

The sample taken from the Khalzanburgedei deposit in Khovd province. In September 2017, I went to take samples and familiar with Khalzanburgedei deposit. During this time I learned a lot of things from German geologists such as how to identify minerals and know Khalzanburgedei deposit geological situation. These things are very helpful to me to understand rare earth properties and why rare earth is so important to countries.

Main objective of sample preparation in the thesis is first to determine or take good representative sample and improve sampling. Therefore, I focused on sampling methods and their factors which affect sampling efficiency.

For the preparing sample preparation:

A total of 800 kg samples for the testwork were taken from the main section of Khalzanburgedei deposit. In experiment, totally 74.5kg sample were used to determine the preparation condition for the rare earth polymetallic ore of Khalzanburgedei deposit.

The sample was crushed by hammer to suitable size for the jaw crusher due to bulk sample size was more than 20cm. Later on, it crushed a jaw and roll crusher to -1.5 mm and split into 1.5kg and 2.5kg amount of subsamples. Thus two different samples are used for comparing grinding time optimization. After grinding the one of the subsamples was further split into 100g amount of sample for chemical analysis. The analysis studied for 63 μ m and 125 μ m over size samples. Afterward thus sizes chemical analysis would be compared with mineralogical analysis (which investigated in Germany).

There are conventional sampling methods to taking good representative samples. The representative sample is taking a small amount of material that accurately represents the whole mass. Sampling is the first most important step in mechanical processing tests. Obtaining representative and reliable sample of any bulk sample for tests is of the most importance. The size of the laboratory sample is important. Too small a sample will not be representative, and too much sample will be unnecessary as well as not representative. In a laboratory, we need to take a good representative sample from the bulk sample before performing sieving, chemical analysis and separating metal from the ore (concentrating).

Taking good representative sample should follow some procedure:

- Design of sampling plan
- Obtaining the samples from the bulk sample
- Reduction and preparation of 1 or more laboratory samples (how many samples needed for test work)
- Analysis of sample

There are main three action for reaching test samples first is reduced sample bulk sample divided into 1 or more identical portions and laboratory samples which prepared from the reduced samples for test samples. The test sample prepared from laboratory sample by grinding, sieving and drying (if sieving is wet). Followign size reduction, the required size should be obtained from the bulk sample using a specific sampling technique. There are several laboratory sampling techniques each of which is usually suitable for handling a certain sample size. These techniques are :

- **Method of coning and quartering**

This method is used for splitting a large sample (maximum 50kg) to obtain a sample of several kilograms. Before using coning and quartering, we need prepare clean plate and tools which needed for splitting samples. Coning and quartering is a simple procedure useful with all powdered materials and with sample sizes ranging from a few grams to several kilograms. Additionally this method should be repeated until the proper sample size needed for a certain test is obtained. This method only efficient for the large bulks around 50kg sample. The method is not efficient for small samples because the obtained sample would be poor. Therefore, this technique used in large bulk samples to obtaining good representative sample.

The procedure of coning and quartering:

1. Starting sample weight (bulk sample) around 50 kg
2. Prepare working area
3. Clean plate (If it is steel plate that would be good for splitting)
4. Spread out sample
5. Mix the samples and shovel it into conical heap
6. Flatten the cone by pressing the top without further mixing
7. The top surface of the frustrum marked into four quarters using shovel or a hard stick
8. Discard 2 opposite quarters using shovel
9. Thoroughly mix the 2 remaining quarters, shovel them into a cone
10. Repeat quartering and discarding procedures until the sample is reduced to needed size around 1.5 to 2.5kg

Thus procdeure takes at least 30 min to take needed size and good representative samples.

- **Method of Jones riffle**

This techniques uses mechanical quartering device riffler. The sample divider are particularly useful with large samples. The rifflers are dividing the sample totally same parts. These device consist of a series of chutes thta run in alternating dirctions, so that when material is goes into the top of the splitter, it flows through chutes and is randomly

divided into two same fractions. One of the fraction could be split again and the procedure can be repeated until a sample of the desired size is obtained, This devise is the most accurate mehod of extracting representative samples from dry granular or powdered material.

Main procedure of this experiment in thesis to taking good representative sample:

1. Randomly select the ores from the large ore sample around 80kg.
2. Determine the suitable feed size for primary crusher then crush the bulk sample by using hammer until proper size for jaw crusher.
3. Crush bulk sample until -6 mm by using jaw crusher
4. Secondary crushing using roll crusher and the sample must crushed until -1.5 mm
5. Use vernier caliper to determining output size -1.5 mm in roll crusher
6. Weight the crushed sample
7. Prepare taking representative sample
8. Should use coning and quartering method
9. Divide into two bulk sample for 35kg and 40 kg cause coning and quartering method possible for maximii
10. Prepare clean flat surface
11. Sample mixed and heaped into cone
12. Mark into four quarters using a shovel
13. Remove the opposite quarters
14. Repeat the process until the suitable size for testwork
15. Split into subsamples for 1.5 kg and 2.5 kg

In my experiment 50 kg subsample used in grinding time optimization, sieving , bond test and chemical analysis. The rest of bulk sample will used for concentration part and any practical experiment next academic year. All 15 steps are performed in taking good representative sample. One of the main purpose in sample preparation is to present general subsampling strategy which means introducing sample preparation procedure in laboratory. As I mentioned the objective of taking good representative sample is reducing bulk samples and the distributing same amount of subsamples each screen size. I think knowing good representative sample is after screening result that could be express the representative sample is good or not. The selecting representative sample has little bit error which can expressed for standard deviation . In laboratory , the standard deviation was 6.5 % If we are using coning and quartering method due to bulk sample weight.

Following sample preparation procedure this identifies the subsampling results. This section also suggests which technique is good for bulk sample. Provided in this section is a general

introduction to subsampling procedures. This procedure focuses on a general strategy to minimize sampling error to obtain good representative samples.



Figure 4-3 Bulk sample



Figure 4-2 Prepare for using coning and quartering method



Figure 4-4 Mark the four quarter top of the ore



Figure 4-5 After Marking the removing opposite quarter the blending again



Figure 4-6 Repeating previous steps

4.2 Size reduction

As I mentioned the crushing process is comminution part due to it reducing size needed for test work. The objective of comminution is to produce smaller particles from larger ones and size reduction is increase surface area to separate the valuable mineral from the ore. There are some factors which influence size reduction.

The factors are:

- Hardness
- Material structure
- Abrasiveness
- Softening temperature
- Moisture content
- Crushing strength

For instance, The Hardness could express a surface property of the material. If material is so hard then size reduction will be more difficult to reduce. Thus hardness measured by Moh's Scale (Moh's Scale= 1 is for graphite , <3 is for soft material , >7 is for hard material , =10 is for diamond)

The comminution theory is the typically used for size reduction which includes different operations such as crushing and grinding.

Crushing

A crusher is a device performed to reduce large rock into smaller portion. The process of transferring a force amplified by mechanical force through a ore made of molecules that bond together more strongly is called crushing process. There are some size reduction ways such

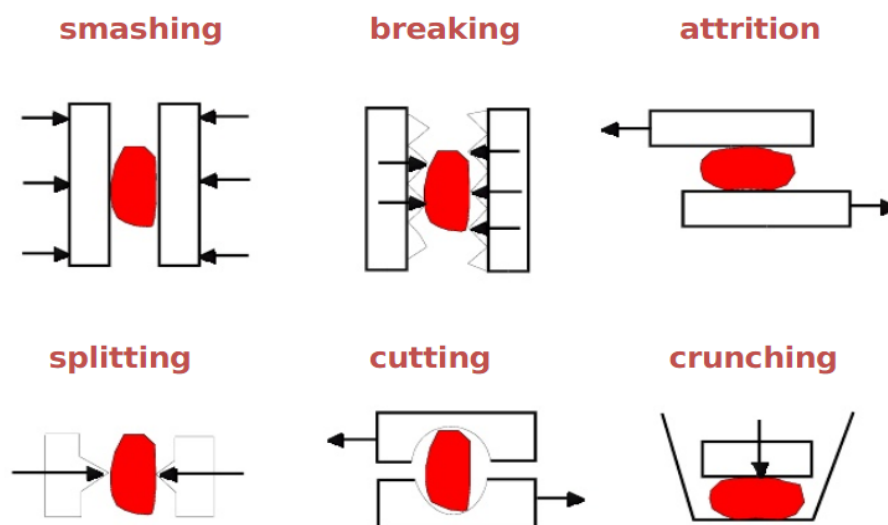


Figure 4-7 Types of mechanism of size reduction

as smashing, breaking, attrition, splittings, cutting and crunching

During mining operations that use crushers. It is generally dry operation and usually performed in two or three stages. The crusher reduction ratios ranging from three to six in each stage. The reduction ratio of crushing stage define as ratio of maximum particle size entering to maximum particle size leaving the crusher. There are 2 stages with primary and secondary crusher. Primary crushers include jaw crusher which used in this experiment and Secondary crusher is roll crusher. The roll crusher (secondary crusher) use to reducing size around -1 mm or 1 to 2 mm.

Jaw crusher

The jaw crusher is primary crusher that received large bulk samples of rock directly from the mines. Then it impact on a rock particle placed between a fixed and moving plate (jaw). Our laboratory jaw crusher feed opening size is 100mm and product size is <6mm (Table 4-1). The Jaw crusher main function is to reducing ore which comes from mine (primary reduction). The laboratory jaw crusher type is 5E-JCA 150x125.

SPECIFICATION OF JAW CRUSHER	
Model	5E-JCA 150x125
Size of the feed inlet	150x125mm
Feed size	<100mm
Discharge size	<6-38 adjustable
Moisture adaptability	<12%
Approx. Hardness of Feeding sample	HRC 48-55
Throughput	500-2000kg/h
Power supply	3phases 380 V
Power of electric motor	4kW
Net weight	378kg
Dimension (LxWxH)	1046mmx600mmx1090mm

Table 4-1 Specification of Jaw crusher

The jaw crusher it consists of a set of vertical jaws, one jaw being fixed and the other one is being moved back and forth relative to it by a pitman mechanism. The device crushed the ore progressively smaller and smaller as it travels downward until it is to escape from bottom opening. There are two types of jaw crusher such as Blake and Dodge jaw crusher. Main difference is dodge jaw crusher the moving jaw is pivoted at the bottom and In the black jaw crusher the moveable jaw is pivoted at the top.

Roll crusher

Roll crusher is secondary crusher that received reduced ore from primary crusher. In this case, we ordered roll crusher from LAARMANN LCC. After receiving roll crusher we fixed it

and prepared for the experiment. The type of roll crusher is LRMC which is a laboratory roll crusher and its suitable for milling and homogenizing soft, hard and brittle material in the dry state. The closed milling system guarantess a good recovery of the samples. Due to the design of the machine the roll crusher can also operate continuously or can be combined with a Jaw crusher.

The roll crusher are used for producing for addidtional reduction in the sizes ore after the output of quarry has been subjected to one or more stages of crushing. In theorotically roll crusher maximum reduction ratio is 4:1. Roll crusher will only crush ore down to minimum particle size about <1 mm. A roll crusher crushes using compression with two rolls rotating about a shagft, towards the gap between the Rolls. The particles are drawn into the gap between the rolls by their rotating motion and a friction angle formed between the rolls and the particle which called nip angle. Th nip angle could affect little bit affect of reducing size reduction.



Figure 4-8 Jaw crusher



Figure 4-9 Roll crusher

4.3 Grinding time optimization

Grinding is second stage of size reduction. It can be wet and dry. In grinding, where liberation size for individual minerals can be reached. Size reduction by crushing has a size limitation for the final products. If we want or the test work require further reduction, say below 100 micrometer , we should use the process of grinding.

There are two main objective if grinding process are:

- To liberate individual minerals trapped in rock crystals (ores) and thereby open up for a subsequent enrichment in the form of separation.
- To produce micrometer particle size from mineral fractions by increasing the specific surface. If are doing size reduction that means the ore surface is increasing by stages.

Factors affecting ball mill grinding efficiency:

Grinding reduction ratio – It defined ratio of feed top size and grinded output top size. The grinding efficiency would increase If grinding reduction ratio is small amount.

Feed preparation –mill performance is related to the complete size distribution of the feed materialan. Thus, size distribution influence performance of the grinding process.

Grinding medium- diameter of grinding medium is one factor that affects. For the different diameter is compared, the longer units being utilized for high reduction ratios and shorter ones where overgrinding happen

Water volume – The water content in ore will influence the working efficiency of ball mill

In this experimnet, I used laboratory ball mill to determining grinding time optimization

Ball mills are usually the largest energy consumers within a mineral concentrator. Therefore, an efficient use has a great impact on performance and cost implications. Comminution is responsible for 50% of total mineral processing cost. Ball mills are deal with to grind ores, especially the more hard surface ores, to finer sizes than can be produced economically in other size reduction machines such as hammer mills. The ball can be operate two term with dry and wet(slurry) grinding. Dry grinding must be less than 1 % moisture by weight. For wet grinding, the range of solids content in wet ball mill slurries is from 65 to 85% by weight. The wet grinding used to prepare the feed material for unit operation such as flotation, gravity separation, magnetic separation and leaching that require slurry of liberated valuable mineral and unwanted gangue particles. Dry grinding application is when mineral can not be dewatered econonmically to the required moisture level and example is cement clinker must be ground dry.

In a laboratory, we can use both grinding process to determine grinding time optimization or any testwork. However, comparing dry grinding and wet grinding process the dry grinding requires about 30% more power than wet grinding for comparable size reduction and dust losses of dry grinding is much higher than wet grinding. There are several types of mills such as rod mill and ball mill. These ball types depends on how much size needed in testwork. For example, the ore could grind by ball mill until 20 micron and you can see all type of mill grinding capacity from the figure 4-10.



Figure 4-11 Ball mill

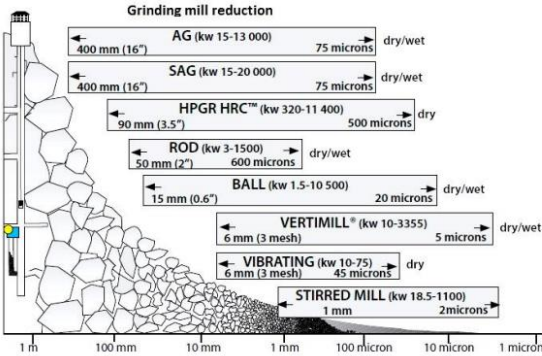


Figure 4-10 Different types of grinding mill reduction

For grinding time optimization:

The bulk samples was crushed -1.5 mm by jaw crusher and roll crusher then split into 1.5kg charges for use in testwork. Grinding test were done to determine the time needed to grind the sample to the liberation size range (10-200µm) for effective separation. Grinding was performed using an ball mill (dimensions: pamel 460x600, 1600x850x1000) at increasing grinding times but constant rotation speed and sample charge (1.5 kg sample in 1.5L water with 15kg steel ball and 2.5 kg sample in 2.5L water with 25kg steel ball). The grinding ratio was 10:1:1 which based on project which I was involved two years ago.

In this experiment, the ball mill used for grinding time optimization. For 1.5 kg and 2.5 kg thus size are used in experiment. The grinding ratio was same both sizes which based on grinding capacity theory cause the shell capacity must be filled between 30% to 50%. Having efficiency grinding solid with water ratio must be 1:1. The ore with water form in slurry which state determine ore weight, volume and ball mill efficiency. The grinding solid with water ratio could determine after experiment result. First experiment was started to compare between dry grinding and wet grinding. After that I chose high particle size distribution and no dust losses type of grinding. Then totally I did 10 times wet grinding with 1.5kg sample and 6times wet grinding with 2.5kg to determining time needed P80 and checking 30-50% filling ore with steel and water that are really affect grinding result.

Working procedure:

1. Steel ball, at least 30% compared to shell capacity , must be put into empty shell
2. Then, put in samples into shell with ratio 1:10to the steel ball
3. Check if the ball mill is closed properly.
4. Set revolution speed is 30 rev/min.
5. As soon as grinding process finishes, switch off machine by pressing stop button
6. Set input door to the starting position by pressing white button.
7. After finished the process , switch off the machine from the power supply, Among operations, the shell must be cleaned by using water

4.4 Particle Size analysis

Screening is a simple technique for separating particles of different sizes. Sieve analysis is accomplished by passing known weight of sample material successively through finer sieves and weighting the amount collected on each sieve to determine the percentage weight in each size fraction. Main objective of particle size analysis to assess the particle size distribution of the ore by allowing the material to pass through different sizes of sieves .The sieve analysis can be used many materials including sands, crushed rock, clays, soils and coal. The particle siz analysis has huge importance in determining the quality of grinding.

The Laboratory sieving tests are used to determine feed 80% passing size and product 80 % passing size. Also it can determine any passing percentage such as F50 and P50. F80 is Laboratory sizing devices are linked to obtain size fractions for variety of studies such as to determine degree of liberation of an ore, to asses the effect of size on efficiency, and to measure particle size distribution.

In this experiment I investigated griding time optimaztion which experiment is performed screenig test to determine the percentage of different screen sizes. The screening carried out wet screening due to no mass loss and good distribution of particle each size. I follow below sieving procedure to determine quality of grinding time.

Sieving procedure:

Screen after grinding product each given minut such as 15 min and 25min

1. Write down the weight of each sieve and the the bottom pan to be used in the analysis (if want to measure very narrow)
2. Make sure all sieves are clean
3. Assemble them from large size to small size sieve
4. Place the sieve in the automat sieving machine
5. Set the time attached to shaker for 15 minutes whcih based on project which i was involved 2 years ago

6. Intensity should be 65 in dry and wet sieving
7. When the sieve shaker has stopped, remove the sieve stack
8. Now record the ore mass of each sieve and pan (should use analytical weigher)
9. Do analysis using data from sieving

Data Analysis

Obtain the mass of ore retained each sieve by subtracting weight of the empty sieve from the mass of sieve +retained soil , record the mass as the weight retained on the data sheet. The sum of these retained masses should be approximately equals the initial mass of ore sample. Then calculate percent retained on each sieve by dividing the weight retained on each sieve by the original sample mass.Finally calculate the percent passing by starting with 100 percent and subtracting the percent retained on each sieve as a cumulative procedure.

For example should follow below way of calculating process:

1. Percentage retained =weight retained/weight of sample
2. Weight passing through= weight of sample-weight retained
3. Percentage passing through=(weight passing through/weight of sample)* 100%

Weight sample : 1500g						
Sieve no.(mm)	Weight Retained (g)	Percentage Retained (%)	Weight passing through (g)	Percentage passing through (%)	Cumulative %retained	Cumulative % passing Through
2	487.1	32.50	1011.87	67.5	32.5	67.5
1	438.87	29.28	1060.1	70.7	61.8	38.2
0.5	200.42	13.37	1298.55	86.6	75.1	24.9
0.25	118.24	7.89	1380.73	92.1	83.0	17.0
0.125	81.72	5.45	1417.25	94.5	88.5	11.5
0.063	66.85	4.46	1432.12	95.5	92.9	7.1
0.032	60.1	4.01	1438.87	96.0	97.0	3.0
0.02	35.35	2.36	1463.62	97.6	99.3	0.7
pan	10.32	0.69	1488.65	99.3	100.0	0.0
Total	1498.97	100	P80=1.38423mm			

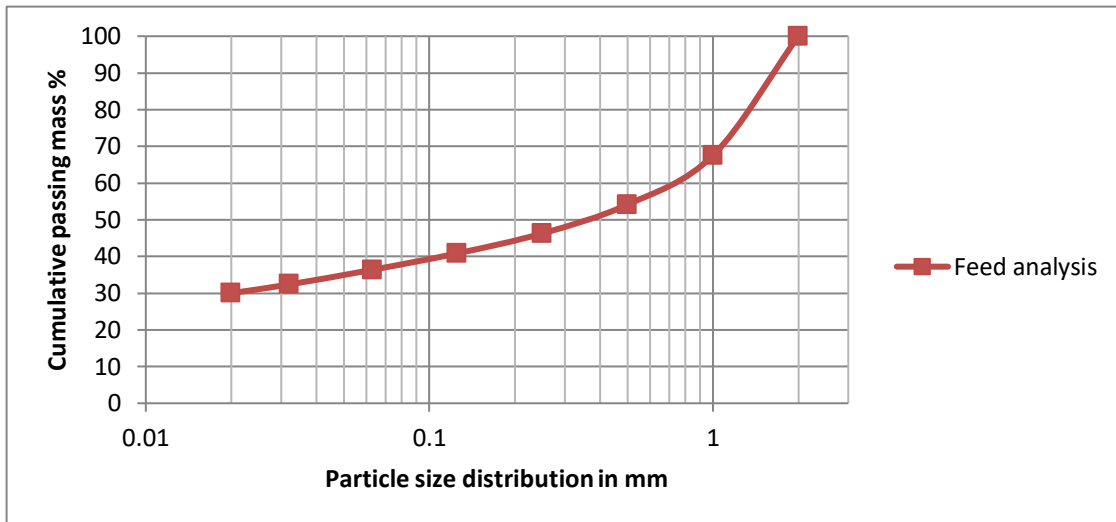


Figure 4-12 Example of particle size distribution curve

4.5 Chemical analysis with mineralogical analysis

Chemical analyses of the sample by XRF or AAS were conducted at Central Geological Laboratory. The contents of rare earth elements in different sizes such as on 63 μm and 125 μm screen by chemical analysis method.

More than 40 elements were determined in chemical analyses and the results purpose was to comparing mineralogical analysis result. Moreover, we would prove our experiment. The all result comes from this chemical analysis.

Mineral Liberation Analysis (MLA method QEMSCAN) was done to identify mineral in Khalzan burgedei deposit mineral and to observe mineral association and liberation sizes of the valuable minerals. The REE, Zr and Nb bearing minerals identified were zircon parisite-(Ce), pyrochlore, bastnasite-(Ce), britholote-(Ce) and synchysite-(Y). The gangue minerals are generally quartz, albite, K-feldspar and arfvedsonite. Yttrium is contained in Zr silicate minerals (gittinsite, zircon), synchysite – (Y), and pyrochlore while light REE are contained in rare earth carbonate minerals (parisite-(Ce)), Heavy rare earth elements and Y in Zr silicates are low, the Zr silicates are the most abundant among the valuable minerals. Thus elements liberation sizes of the valuable minerals range from 10 to 250 μm .

5 Result and Discussion

The experiment of thesis is to determine grinding time optimization and to determine optimum time of grinding in two different P80 values should be carried out and compare with the mineralogical analysis result. The mineralogical analysis result compare with chemical analysis in two differents sizes. Results will be carried out screening after crushing and screening after grinding time optimization. Also content of Rare earth elements

Sample preparation

In this section we need to determine is that really good representative sample or not. For the bulk sample used coning and quartering method with riffing method to take representative sample. After coning and quartering I used Jones riffle method to split into 1.5kg and 2.5kg sample. The method was good splitter .The result express us using coning and quartering method with jones rffle splitter are I think the good representative sample is distribtion of sample.

Feed	2500		Sieving 2
size[mm]	mass[g]	mass[%]	cumulative mass[%]
2	658.73	26.37	100.00
1	748.98	29.98	73.63
0.5	372.34	14.90	43.65
0.25	230.85	9.24	28.75
0.125	176.3	7.06	19.51
<0.125	311.13	12.45	12.45
Total	2498	100.0	F80=1.241471

Feed	2500		Sieving 3
size[mm]	mass[g]	mass[%]	cumulative mass[%]
2	677.81	27.15	100.00
1	751.59	30.11	72.85
0.5	368.5	14.76	42.74
0.25	224.71	9.00	27.98
0.125	160.59	6.43	18.98
<0.125	313.31	12.55	12.55
total	2497	100.0	F80=1.26336

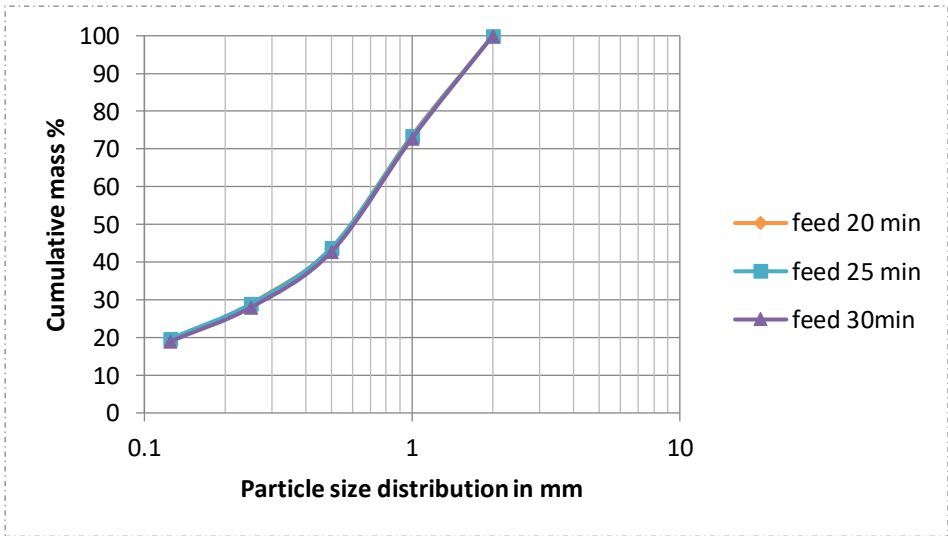


Figure 5-1 Paricle size distribution curve for feed

After sieving result, The feed particle size distributions are compared each other to see is that good representative sample or not. From Table 5-1 and 5-2 size analysis start with 2 mm and bottom size is 20µm. For example comparing sieving 2 and 3, the mass percentage of each size are very similar. At this point that express the taking representative samples were taken good. Moreover the (Figure 5-1) shows us The three feed F80 almost same that means taking representative samples were along good procedure.

Grinding time optimization

The mineralogical analysis have shown that the ore's reasonable grinding size for the beneficiation would be around 80 % passing 63-125µm. Therefore, Our purpose was to determine grinding time optimization when ore reduction would be reach 63 µm and 125µm. The first hypothesis was set to starting with 25 min dry grinding to reach 250µm for 1.5kg sample and second assumption was starting with 15 min wet grinding to reach 125 µm for 2.5kg sample due to if increasing mass then its reduction could increase. Main principle of grinding is the reduction of ore always increasing with time.

In this grinding time optimization experiment was deal with screening result and chemical analysis to compare content of REE . I did number of grinding experiment However I took only one dry grinding and 3 wet grinding in result to these result was more reliable.

For grinding time optimization the only 15-45min is needed to grind sample less than 37µm

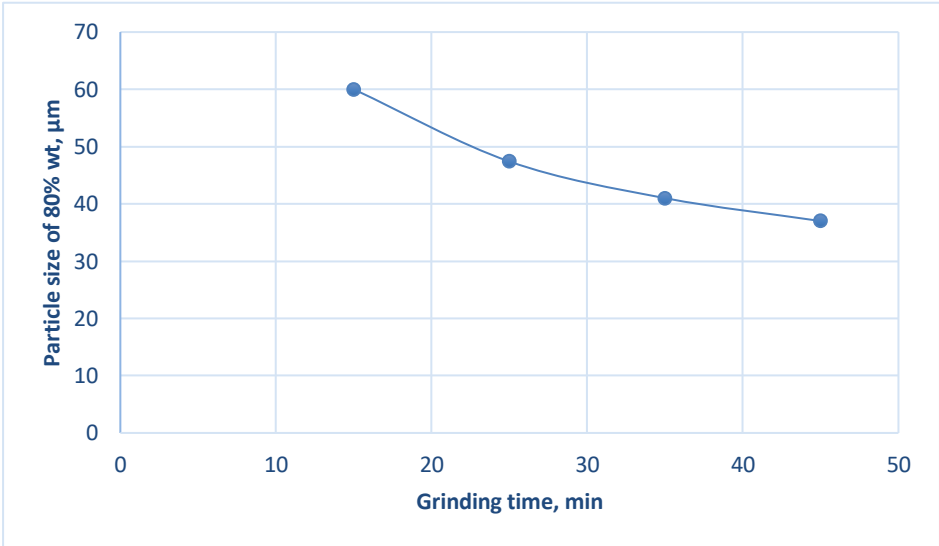


Figure 5-2 Grinding curve for the feed sample (1.5kg)

particle.size. The long grinding time will be needed to reach 20 μm due to presense of many silicate mineral which are generally hard. Yoou can see all result from Figure 5-2, 5-3, and 5-4, 5-5 which are express us the particle size would be decrease while we are increasing grinding time.

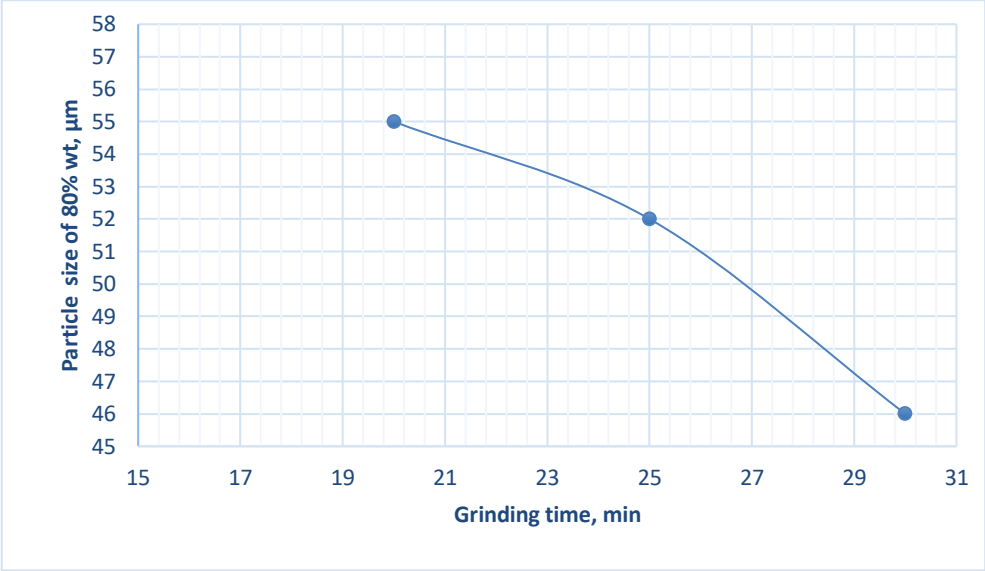


Figure 5-3 Grinding time curve for feed sample (2.5 kg)

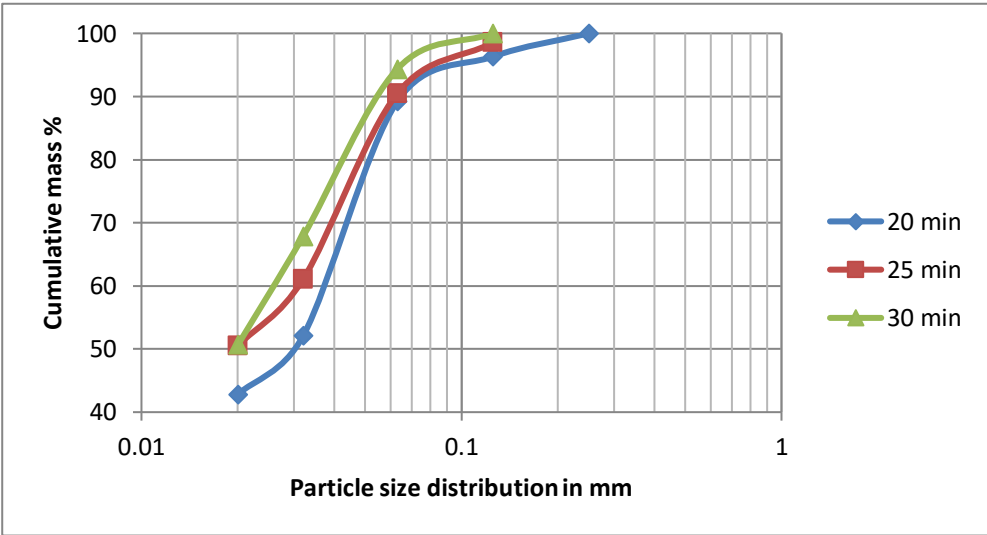


Figure 5-4 Particle size distribution after grinding 20, 25 and 30 minutes for 2.5 kg

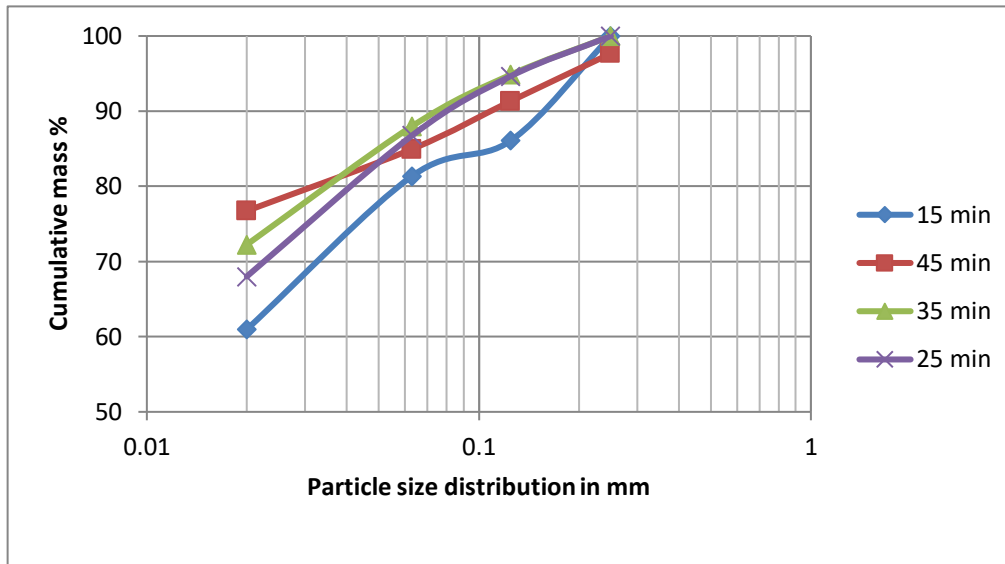


Figure 5-5 Particle size distribution after grinding 15,25,35,45 min for 1.5 kg

Determine ball mill charge

This experiment conducted two different mass such as 1.5 and 2.5kg that mass would affect water volume and ball mass. Generally, The ball ore charge must be 10:1:1 ratio only in ball mill grinding. This means, the ball mill charge is ore+water+ball. Then, The ball charge is determined by the ore size,hardness and ball mill diameter. Meanwhile, ball charge is determined by the operator targetting the balance between grind and throughput, the much high ball charge the more aggressive the milling becomes. With softer rare earth oxide ores lower media charges needed and silicate minerals with rare earth oxide does need more energies to meet the P80 target and an acceptable throughput. There are too many variables to determine ball ore charge. But, In this case I chose two types of ore size such as 1.5 and 2.5kg . For 1.5kg the ratio would be ball mass 15kg and ore size 1.5kg and water volume 1.5L.

The result shows us the with 2.5kg ore size is not effective than with 1.5kg ore size charge. For example, the P80 with 1.5kg ore size of grinding time with 25min is 47 μ m and the P80 with 2.5kg ore size is 52 μ m. We can see this number from figure 4-4 and 4-5. Observing this graph the if ore mass increase the P80 target will be not reach what we want. Because the high mass would affect grinding. This means long time need to reach P80 target If the ore mass is high.

Comparison of dry and wet grinding

Comparison of dry and wet grinding process in ball mill. The research was conducted in a rare earth metals grinding. The following key aspects were tested: processing time, feed size, size of grinding media. The particle size distribution of the product sample was analyzed in the laboratory after each experiment. One of them analyze was between dry grinding and wet grinding. The Figure 25 shows us the particle size distribution of dry and wet grinding. The dry grinding P80 target is 120 μ m and wet grinding P80 is 47 μ m (You can see this number from Table 5 – 1. The result illustrated us the wet grinding is more efficiency than dry grinding. Therefore, All experiment was conducted in wet grinding type.

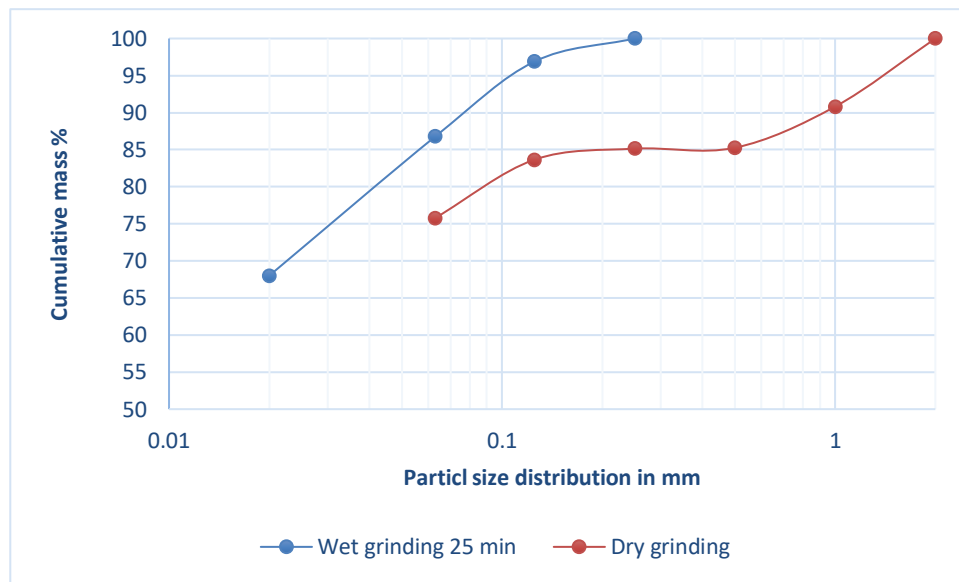


Figure 5-6 Comparison of dry and wet grinding with 25min

Feed	1499		Dry Grinding 25min
size[mm]	mass[g]	mass[%]	cum.mass[%]
2	132	9.19	100
1	65.36	4.55	90.81
0.5	16.16	1.12	86.26
0.25	21.33	1.48	85.14
0.125	113.05	7.87	83.65
0.063	1088.9	75.79	75.79
Total	1436.8	100	P80=120μm

Feed	1497		wet grinding 25mn
size[mm]	mass[g]	mass[%]	cum.mass[%]
0.25	45.63	3.12	100.00
0.125	147.95	10.10	96.88
0.063	274.9	18.77	86.78
0.02	996.15	68.01	68.01
Total	1465	100.00	P80=47

Table 5-1 Dry and wet grinding analyze

Comparison of chemical and mineralogical analysis

Our purpose was rare earth metals liberated in 125µm due to mineralogical analysis mass fraction. The mass fraction of rare earth minerals in mineralogical analysis are liberated in 125-250µm. This means, more efficiency and economically size is 125µm which proven in Aachen's project on Khalzanburgedei deposit (you can see figure). Therefore, This study attempt to investigate and prove all mass fraction generally liberate in 125µm.

After experiment I gave sample to geological central laboratory to do chemical analysis and determine mass fraction of rare earth minerals.

Mineral	Mass % in Fraction				< 250 µm
	< 250 µm	125-250 µm	63-125 µm	< 63 µm	
Quartz	28.03	30.23	25.23	16.52	24.96
Arfvedsonite	2.34	2.31	2.46	1.86	2.22
K-Feldspar	20.85	22.96	22.28	19.88	21.89
Albite	34.18	30.11	40.09	53.29	39.42
Hematite	2.78	2.26	1.61	1.25	1.80
Pyrochlore	0.27	0.52	0.39	0.78	0.56
Fluorite	3.37	3.38	2.62	2.39	2.90
Carbonate	0.73	0.74	0.50	0.45	0.59
Synchysite-(Y)	0.52	0.30	0.20	0.08	0.21
Parisite-(Ce)	0.18	0.13	0.08	0.11	0.11
Bastnasite	0.24	0.09	0.12	0.07	0.09
Zircon	3.23	3.97	2.65	1.78	2.99
Gittinsite	0.22	0.19	0.12	0.10	0.14
Rutile	0.37	0.22	0.19	0.18	0.20
Ilmenite	0.18	0.29	0.19	0.10	0.21
Other	2.50	2.30	1.29	1.16	1.71

Figure 5-7 Mass fraction

No	Lab No	Sample No	SiO ₂ %	TiO ₂ %	Al ₂ O ₃ %	ΣFe ₂ O ₃ %	CaO %	MgO %	Na ₂ O %	K ₂ O %	MnO %	P ₂ O ₅ %
1	608	1.5 kg (63 ppm)-	73.94	0.288	11.11	2.80	1.31	<0.01	3.62	3.69	0.076	<0.005
2	609	1.5 kg (125 ppm)-ore	74.00	0.353	9.21	3.50	1.71	<0.01	1.87	4.82	0.080	<0.005
3	610	2.5kg (63 ppm)-ore	73.41	0.280	10.92	3.15	1.50	<0.01	3.03	4.14	0.091	<0.005
4	611	2.5kg (63 ppm)-ore	67.68	0.330	12.09	4.87	2.55	<0.01	3.18	3.84	0.164	<0.005

Table 5-2 Chemical analysis

The samples which taken from after grinding as determined by chemical anal analysis is shown in Table 5-2 and 5-3 and 5-4. The major components are SiO_2 (73.92%), Al_2O_3 (11%), Fe_2O_3 (3.5%), Grades for valuable elements are Ce (956mg/kg), Nb (1762mg/kg), La (361mg/kg) and Y (1029mg/kg), Zr(1%) for 2.5kg sample. Low P_2O_5 (0.005%), suggests that REE-bearing phosphates (apatite, monazite, xenotime) are not abundant. Th and U contents (224mg/kg and 74 mg/kg) are not very high compared with ordinary REE deposits. Also, we can observe the mass fraction is high on 125ppm. Moreover, we can prove our experiment compared with mineralogical analysis.

№	Sample №	Ce mg/kg	Co mg/kg	Cr mg/kg	Cs mg/kg	Cu mg/kg	La mg/kg	Mo mg/kg	Nb mg/kg	Ni mg/kg	Pb mg/kg	Pr mg/kg
1	1.5 kg (63 ppm)-ore	730	16	332	<30	<5	333	11	1332	127	138	108
2	1.5 kg (125 ppm)-ore	790	18	198	<30	111	361	17	1158	17	155	90
3	2.5kg (63 ppm)-ore	591	16	443	<30	13	245	33	986	185	143	75
4	2.5kg (125 ppm)-ore	956	26	1120	<30	46	405	35	1762	501	306	75

Table 5-3 Chemical analysis

№	Sample №	Rb mg/kg	Sb mg/kg	Sc mg/kg	Sm mg/kg	Th mg/kg	U mg/kg	V mg/kg	W mg/kg	Y mg/kg	Zn mg/kg	Zr mg/kg
1	1.5 kg (63 ppm)-ore	567	<40	<10	83	127	43	<15	57	709	423	>1.00 %
2	1.5 kg (125 ppm)-ore	750	<40	<10	82	153	57	<15	69	874	441	>1.00 %
3	2.5kg (63 ppm)-ore	634	<40	<10	63	113	45	<15	55	710	560	>1.00 %
4	2.5kg (63 ppm)-ore	583	<40	<10	101	224	74	<15	65	1029	1233	>1.00 %

Table 5-4 Chemical analysis

6 Conclusion

The aim of this study focus on the mineral processing of the Khalzanburgedei polymetallic rare earth mineral ore. Take representative sample and preparation process should be done in this thesis. Also, this research was to determine grinding time optimization and carried out sieve analysis in two different P80 values. During this study I wanted to achieve P80 is less than 63 μ m with short time of grinding.

The two objectives of the research were:

The first purpose was to develop sample preparation of Khalzan Burgedei rare earth polymetallic deposit. The second goal was to compare chemical analysis result with mineralogical analysis. The rare earth minerals are liberated in 125ppm by mineralogical analysis that P80 is proven. Therefore, Our experiment based on mineralogical analysis. Then we needed to do taking good representative sample, crushing, grinding, sieving. After that experiment the one of the subsamples goes to Central Geological Laboratory for determining content of REE by chemical analysis.

The conclusions are as follows:

In conclusion, it is practical that solutions are prove real laboratory experiment. The coning and quartering with Jones riffle method is taking good representative sample. Only coning and quartering is not enough to take good representative sample. It should be more precisely with Jones riffle. After many times of taking samples the too small size is not representative (because If sample is too small size the particle size distribution is not uniformly which will be affect P80 target) and too much sample will be unnecessary. Therefore, we should carefully take representative sample. To using coning and quartering method with Jones riffle that was so effective that comes from feed particle size distribution result. It was generally same F80 and each size was same. Conclucing sample preparation step, the coning and quartering method was suitable for bulk sample to take representative sample. Moreover, it will be affect next process stage positively.

Crushing and grinding time optimization

The sample taken from the deposit that samples are bulk which must be small size to grind. We need to use roll crusher to reduce size until 1.5mm. There is a reason to reduce sample size until 1.5mm. The reason is short grinding time required small feed size sample. For obtaining grinding time optimization to reach less than 63 μ m, there will be some factor to affect time such as ball ore charge and ball mill diameter.

An important finding from this optimization is that rare earth minerals easily grind in wet grinding type especially in ball mill wet grinding. This data that mentioned in result this would

make a little contribution to developing sample preparation and real processing stage. Moreover, since this research the GMIT students understand how to determine grinding time optimization and what factor could affect time of grinding, it could have important implications for gaining knowledge for students doing sample preparation and determining grinding time optimization. The time of grinding should be short due to mills are taking 50% energy consumption of factory.

The main result comes from chemical analysis for rare earth minerals. Observing results the minerals was generally liberated in 125ppm. Therefore, I decided that number is suitable size for liberating rare earth minerals for grinding with 25 minutes. After comparison between mineralogical analysis and chemical analysis the result was matching. Concluding this section, we could do experiment in our laboratory due to proved by comparison result.

The thesis began with a broad introduction to the study which identified its significance and briefly indicated what was to come the first chapter reviewed introduction of Rare earth polymetallic minerals that include geological distribution, properties, major ore minerals, World usage and Recycling. The second chapter mentioned the Rare earth deposits in Mongolia. The third chapter outlined literature on beneficiation unit operation such as gravity separation, magnetic separation and leaching. Experimental methodology describes what works I did in this study, while the fifth chapter presented the results of these studies and answered research objectives.

7 Recommendations for future research

In this thesis, I identified various areas where further research was needed, or a more comprehensive review of the documents developed for this thesis. The areas of further research include the following:

- Determining error for sample preparation that was necessary things to do in thesis, but the materials are not enough in online to fully understand. Therefore, the person who are choosing rare earth beneficiation unit operation should be investigate this one for further research.
- The roll crushers output sizes were difficult to set, However I used vernier caliper.
- More investigation needed ball mil charge.
- 25 min wet grinding is suitable for beneficiation unit operation.
- Rare earth element minerals should be seperated by magnetic separation and flotation based on their properties.
- While the study showed that whole process of wet grinding and sieving needed more time than I planned. Should be focus on planning of experiment.

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9 APPENDIX

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Захиалгын дугаар : ЦЛ 2018/0131
 Захиалагчийн нэр : Монгол Германы хамтарсан Ашигт малтмал технологийн их сургууль

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Нэгжийн нэр : Хими физик аргын тусгай
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 Шинжилсэн элементийн тоо : 44
 Дээжний боловруулалт : ГТЗ-д боловруулсан
 Дээжний тоо, төрөл : 4, хуурийн дээж
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 Хугацаа авсан огноо : 2018.06.04
 Шинжилгээ эхэлсэн огноо : 2018.06.05
 Шинжилсэн огноо : 2018.06.06
 Хуульчны тоо : 2

Тайлбар: (1) АСЗ-Аттестатчилсан стандартчилсан загвар

Энэхүү шинжилгээний дүн нь захиалагчаас ирүүлсэн тухайн дээжинд хамаарах бөгөөд зөвхөн эх хувь нь хүчинтэй.

Тасгийг дараа (галиу) илгээгээр
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 Т. № 02
 Хяналтгүй шинжлэгч
 (галиу үест)

А.Ариунбат (нр)
 Б.Долзолмаа (нр)

Хэвлэсэн огноо: 2018.06.06

Манай байгууллагаар үйлчилгээний биарлагатай.

Хуульч (02)

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ШИНЖИЛГЭЭНИЙ ДҮН

Захиалгын дугаар: ЦЛ 2018/0131

Захиалагчийн нэр: Монгол Германы хамтарсан Ашигт малтмал технологийн их сургууль

№	Лаб №	Дээж №	Дээжийн тодорхойлолт	SiO ₂ %	TiO ₂ %	Al ₂ O ₃ %	ΣFe ₂ O ₃ %	CaO %	MgO %	Na ₂ O %	K ₂ O %	MnO %	P ₂ O ₅ %	F %	ШХ %	As мг/кг	Ba мг/кг	Bi мг/кг
1	608	A (63 мм)-хүдэр	-	73.94	0.288	11.11	2.80	1.31	<0.01	3.62	3.69	0.076	<0.005	<0.05	1.10	33	47	<5
2	609	A (125 мм)-хүдэр	-	74.00	0.353	9.21	3.50	1.71	<0.01	1.87	4.82	0.080	<0.005	<0.05	1.56	50	94	<5
3	610	B (63 мм)-хүдэр	-	73.41	0.280	10.92	3.15	1.50	<0.01	3.03	4.14	0.091	<0.005	<0.05	1.39	40	48	<5
4	611	B (125 мм)-хүдэр	-	67.68	0.330	12.09	4.87	2.55	<0.01	3.18	3.84	0.164	<0.005	<0.05	2.61	52	80	<5

Чагарын хяналт

1	АСЗ	шифр-121	Аттестатчилсан утга	11.86	0.200	2.72	5.71	32.68	2.78	0.25	1.55	1.670	0.220	-	-	224	307	-
			Шинжилсэн утга	11.93	0.177	2.86	5.92	33.04	2.57	0.23	1.48	1.713	0.205	1.74	30.56	224	311	16

РФА-44

№	Лаб №	Дээж №	Дээжийн тодорхойлолт	Ce мг/кг	Co мг/кг	Cr мг/кг	Cs мг/кг	Cu мг/кг	Ga мг/кг	Ge мг/кг	Hf мг/кг	La мг/кг	Mo мг/кг	Nb мг/кг	Nd мг/кг	Ni мг/кг	Pb мг/кг	Pt мг/кг
1	608	A (63 мм)-хүдэр	-	730	16	332	<30	<5	59	<3	311	333	11	1332	356	127	138	108
2	609	A (125 мм)-хүдэр	-	790	18	198	<30	111	41	<3	458	361	17	1158	382	17	155	90
3	610	B (63 мм)-хүдэр	-	591	16	443	<30	13	57	<3	321	245	33	986	291	185	143	75
4	611	B (125 мм)-хүдэр	-	956	26	1120	<30	46	63	<3	327	405	35	1762	448	501	306	75

Чагарын хяналт

1	АСЗ	шифр-121	Аттестатчилсан утга	27600	-	-	-	-	-	-	21100	-	31	6500	-	1600	2300	
			Шинжилсэн утга	27197	19	98	<30	<5	<3	<3	<15	22137	66	34	6890	<5	1797	2370

Энэхүү шинжилгээний дүн нь захиалагчаас ирүүлсэн тухайн дээжинд хамаарах бөгөөд зөвхөн эх хувь нь хүчинтэй.

Хэвлэсэн огноо: 2018.06.06



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ШИНЖИЛГЭЭНИЙ ДҮН

Захиалгын дугаар: ЦЛ 2018/0131

Захиалагчийн нэр: Монгол Германы хамтарсан Ашигт малтмал технологийн их сургууль

№	Лаб №	Дээж №	Дээжийн тодорхойлолт	Rb	Sb	Sc	Sm	Sn	Sr	Ta	Th	U	V	W	Y	Zn	Zr	
				мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	мг/кг	
1	608	A (63 мм)-хүдэр	-	567	<40	<10	83	105	92	90	127	43	<15	57	709	423	>1.00 %	
2	609	A (125 мм)-хүдэр	-	750	<40	<10	82	117	112	76	153	57	<15	69	874	441	>1.00 %	
3	610	B (63 мм)-хүдэр	-	634	<40	<10	63	97	97	63	113	45	<15	55	710	560	>1.00 %	
4	611	B (125 мм)-хүдэр	-	583	<40	<10	101	119	153	124	224	74	<15	65	1029	1233	>1.00 %	
Чанарын хяналт																		
1	АСЗ	шифр-121	Атгестатчилсан утга	67.12	-	-	-	-	4900	-	946	-	115	-	167	469	-	
				Шинжилсэн утга	65	55	<10	369	<30	5058	<10	977	43	97	11	209	484	32
				Шинжилгээний аргын код	РФА-44													

Энэхүү шинжилгээний дүн нь захиалагчаас ирүүлсэн тухайн дээжинд хамаарах бөгөөд зөвхөн эх хувь нь хүчинтэй.

Гүйцэтгэсэн инженер: Ж.Одбаяр
(гор)