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Investigation of the Mine-ability of Mongolian Phosphate deposits in view of Economic and Environmental future prospects

Bachelor Thesis

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List of abbreviations

PR- Phosphate rock

PG-Phosphogypsum

PR-M- Phosphate rock marketable

Gy- Gray (measure of dose of irradiation)

MNT- Mongolian Tugrik (official currency of Mongolia)

CCI- Capital cost index

USGS- United States Geological Survey

MAP- Monoammonium phosphate

DAP- Diammonium phosphate

MCS- Mineral commodity summaries

vm- Vertical meter

mmt- Million metric tons

Dwb- Humid continental climate

AMC- Australian Mining Consulting

CASP- Citric acid solution of phosphate

REE- Rare earth element

NPV- Net present value

1. Abstract

From an environmental point of view, Compared to the 15 different origin of phosphate mining's toxic metal concentrations, the Burenkhan first deposit content of arsenic is two times higher, lead 0.18 times lower, while uranium six times lower, and strontium is again 0.27 times lower. The biggest environmental problem is related to the phosphogypsum (PG) stacks. PG stacks usually contains heavy metals and metalloids. Furthermore, gypsum stacks are covering a lot of areas and it requires monitoring to avoid failure. There is some utilization of PG stacks to make good quality products by using advanced technology.

From economical perspective, we would say, period of two years payback (Case I) and 3.4 year payback period (Case II) are mineable. If the waste/ore ratio is about 1:1, 2:1 and 4:1, then we could have a chance to mine the ore with a high profit. Otherwise, we cannot mine the deposit economically. Compared to the different version of projects Burenkhan first deposit have a high grade of phosphate rock concentration (P_2O_5), low payback period, and high NPV. Those factors illustrates how to mine in the deposit more efficiently. Also, the easiest international indicator to mine marketable is the concentration of P_2O_5 that should be higher than 30%.

The life time of Burenkhan first deposit is about 18.19 years and the annual operating profits are 91.5 (Case I), 67.6 (Case II) and 16.4 (Case III) million U.S. dollar. Burenkhan first deposit vertical meter (vm) is from 80 to 380. Therefore, it is more economic to extract ore by surface mining method. The cheapest beneficiation techniques are crushing, screening or scrubbing, and de-sliming. The main conventional concentrating technique is froth flotation because this technique is more suitable for quartz, chalcedony, and silica containing phosphate rock minerals. The hardness of the phosphorites is 5-8 in Mohs scale. Therefore, discontinued mining method is more suitable.

2. Introduction

Phosphorus is the most important element for all living organisms. It plays a main role in food production and fertilizers. In agriculture, the growth of living plants is dependent on the amount of phosphorus in soil(1). Phosphate rock (PR) has also known as one of the finite and nonrenewable resources. In recent years, the global population has grown dramatically. Due to the increasing world population, the demand for plant growth fertilizers has increased too.

The world resources of phosphate rock (PR) total 290 billion tons. But five countries dominate with highly concentrated reserves of about 85 to 90 percent of global reserves. China, the U.S, and Morocco are exporting 70% of the total world exports. Dominating phosphorus production and market by only a few countries will lead to unpredictable consequences. For instance, in 2008, when China raised the export taxes to about 135%, which consequently led to a global spike phosphorus prices and supply shortfalls.

Although the world is facing the shortage of phosphate rock, the European Union is concerned about reducing marketable phosphate products in the market. It will need many years to develop reserves and starting new mines, which will lead to an increase in the price of the product. France, Germany, Italy Spain, and the United Kingdom account for over three-quarters of the fertilizer imports of phosphorus in Europe. Domination of phosphorus production and market by only a few countries leads to an unforeseeable increase global phosphate demand, lack of phosphate on the market, and uncertain price increases. According to the US Geological survey's, hurricane, Irma, affected the phosphate production in Florida. Due to that natural disaster the global phosphate demand increased.

During the days of the Soviet Union, Mongolian-Russian geologists did massive explorations jointly the result of which was major deposits. These deposits that contained a high amount of valuable minerals, such as coal, copper, phosphate and other valuable materials.

There are two major world-scale phosphate-bearing basins in the territory of Mongolia, the Khubsgul and Zavkhan phosphate-bearing basins with more than 30 deposits and 20 deposits, respectively. The Khubsgul basin contains 4.5 billion tons of ore reserve and the Zavkhan has 1.2 billion tons of reserve. The worldwide phosphate ore resources are estimated to be around 290 billion tons.

During the current decade, we are concerned about the environmental impact of phosphate production. It requires large amounts of sulfuric acid while the manufacturing of phosphate rocks produces several waste products such as waste rocks, phosphatic tailings and phosphogypsum (PG). According to recent studies, researchers and engineers have established new technologies that can be used to reduce the waste.

The next challenging issue can be the economic evaluation. Mongolia has really bad infrastructure. In order to extract valuable minerals, it is necessary to make some investments in basic buildings. Furthermore, a higher range of productive life time of a mine often requires considerable investment in building roads, employee camp, and mainly in infrastructure. Utilizing new technology in the mine can be reduce both production and recovery costs. Furthermore, Mongolia had the potential to produce phosphate fertilizer, to provide for Mongolian agriculture, and even sell it on the world phosphate market.

3. Phosphate Fundamentals

Phosphate rock obtains in several deposit types, the importance industrial mineral of all deposits is apatite. It is in the form of fluorapatite ($\text{Ca}_5(\text{PO}_4)_3(\text{F})$) and/or carbonate fluorapatite ($\text{Ca}_5(\text{PO}_4)_3(\text{CO}_3)(\text{F})$). The phosphate deposits have three types: Phosphorites; carbonatites and alkaline igneous rocks; guano deposits.

Phosphorites: Marine sedimentary phosphate deposits carries carbonate fluorite with 1 weight percent of fluorine and large amount of carbonate as the phosphate mineral. Francolite is the one of the apatite form. Which is present as nodules or pellets more than two millimeters in diameter and it contains various impurities. The impurities are quartz, clays, iron, oxyhydroxides, organic matter and carbonate. Ions are replacing by the calcium, phosphate and fluorine within the francolite lattice are diverse and mainly contain sodium, magnesium, strontium, carbonate and sulfate as well as other trace elements. For instance uranium, thorium, rare earth elements (REE), yttrium, cadmium, and Zinc.

Carbonatites and alkaline igneous rocks: The form of fluorapatite occur elevated phosphate concentrations (e.g. Russia, Canada). Igneous rock's soluble carbonate minerals removes by weathering processes. Which leads to the natural concentration of fluorapatite and other weathering resistance minerals (e.g. magnetite, pyrochlore).

Guano deposits: it occurs in the tropical zone, commonly tropical coral islands originally bird excrements which have been leached, oxidized and redeposited as amorphous and crystalline phosphates. Commercial guano deposits have largely been mined out, and there has been no waste produced during the production of mining due to the nature of the deposits.

Mineralogy and Geochemistry

Major mineral also contains gangue minerals include framework, ortho, ring, chain and sheet silicates as well as sulfides, oxides hydroxide, sulfates and carbonates. Furthermore, it is possible to found the high amount of uranium, thorium, rare earth element, yttrium heavy metal and metalloid in phosphorite deposit. While carbonatite and alkaline igneous rock related deposits shows high amount of uranium, thorium rare earth element, yttrium, niobium, tantalum, titanium, and zirconium concentrations.

Some phosphate rock have found with high amount of radioactivity characteristics. Uranium and thorium concentrations of phosphate deposits are very different, depends on type of deposits. For example igneous deposits commonly have lower uranium

concentration than sedimentary phosphorites. On the other hand, igneous deposits have higher thorium concentration.

3.1 Phosphate industry in the world

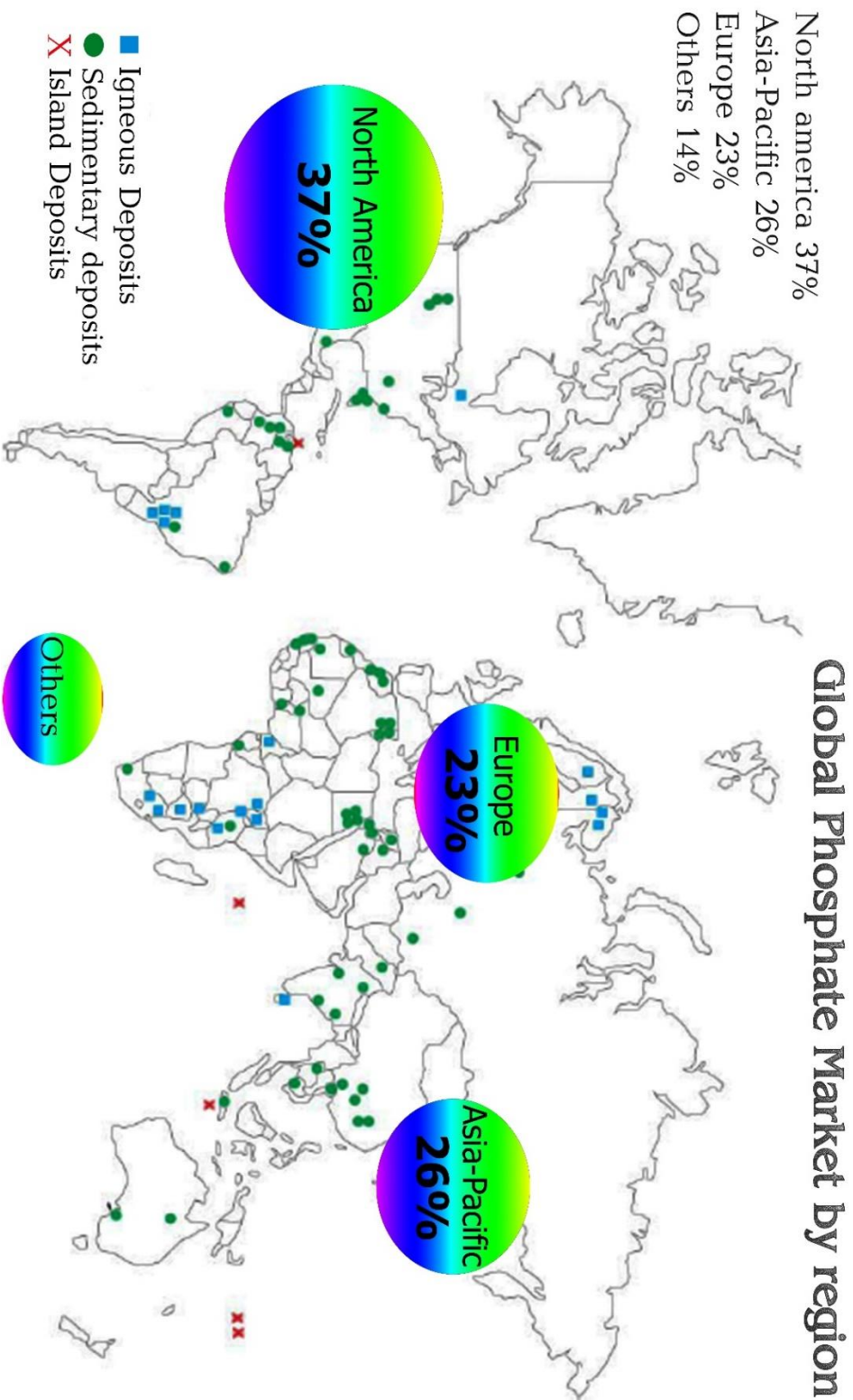
US Geological Survey (USGS) estimated as a global phosphate rock production at 181 million metric tons (mmt) in 2010 as well as 191 (mmt) in 2011. In 2011, the major manufacturers were the US, China, and Morocco, including Western Sahara. Those countries estimated over two-thirds of global production. The Major value chain involves in S.A OCP (Morocco), Israel Chemicals Ltd (Israel), Jordan Phosphate Mines Company (Jordan), PhosAgro (Russia) and Yuntianhua Group (Chinese). Also, phosphate rock extracting the derivatives are Brazil, Jordan, Egypt, and Tunisia.

The main phosphate rocks are exporting from Africa and West Asia with a share of 53.65% and 27.2% respectively in global phosphate rocks exports(1). On the other hand, the large share global imports by region South Asia, Western Europe, and East Asia, with 22.7%, 16.2%, and 14.5% respectively(1). The world-wide phosphate market value estimated at 67.28 Billion in 2015 and it has a perspective to reach 75.117 Billion by 2021(2).

The worldwide phosphorus markets are classified on the basis of a type of resources, as an instance, sedimentary marine deposits, igneous & weathered rock, and biogenic, etc. The largest source for phosphate rocks are sedimentary marine deposits. Nearly, 75% of the global phosphate rocks extracted from sedimentary marine deposits. The second largest source for phosphate rocks are the igneous & weathered rocks. The global phosphate markets segmented on the basis of regions, such as Asia-Pacific, Europe, North America, South America, and Middle East & Africa. In the recent years, the Asia-Pacific regions are dominating the market for phosphate fertilizers(2).

The growth of world-population doubled while the demand for food nutrients will increase. China is a leading country in phosphate fertilizer production. The second-fastest growing market is in South America from 2016 to 2021. In this region, the growths attributed to the rapidly growing agriculture sector. The main factors that regulate the increasing worldwide phosphate market are strict regulation to utilize of phosphate in detergents and reducing the supply of rock phosphate.

Figure 1 Phosphate Market by regions and types of deposits



3.2 World phosphate rock reserves and resources

The majority of earth phosphate rock reserves are situated in Morocco, Iraq, China, Algeria, Syria, Jordan, South Africa, the US, and Russia. We have the possibility to explore new reserves in Saudi Arabia, and offshore projects off the coasts of New Zealand and Namibia although, it is expensive to do exploration(1).

According to the United States Geological Survey (USGS), the global phosphate reserves increased from 16000 Mt to 65000 Mt from 2011 to 2012, and further to 67000 Mt in 2014. The majority of the world phosphate rock reserves and resources increased by four times, based on a 2010 report by the International Fertilizer Development Center (IFDC). A global phosphate rock resources increased from 163000 Mt to 290000Mt. Due to newly discovered new reserves. There was an increase world phosphate reserves from 5700Mt phosphate rock to 51000 Mt phosphate rock in 1989 (4). Economically mine-ability of the ore depends on the conversion factors, on ore grade, the efficiency of the recovery and losses in the beneficiation process. A rough worst-case estimation designated that PR concentrate with 30% P_2O_5 phosphate rock marketable (PR-M) as the measuring unit. The global reserve estimate 58Gt PR-M (Fig. 2). This calculation is about 13% smaller than the USGS estimation. There is no physical phosphate rock shortages in the short term. Prices of phosphorus fertilizer commodities are very stable as well as it has the potential to increase reserves by technological advancements. The annual production magnitude of 0.2Gt PR-M phosphate concentrate and 60Gt amount of PR-M as global reserves(3). Furthermore, some countries PR reserves did not uploaded in the same database (USGS).

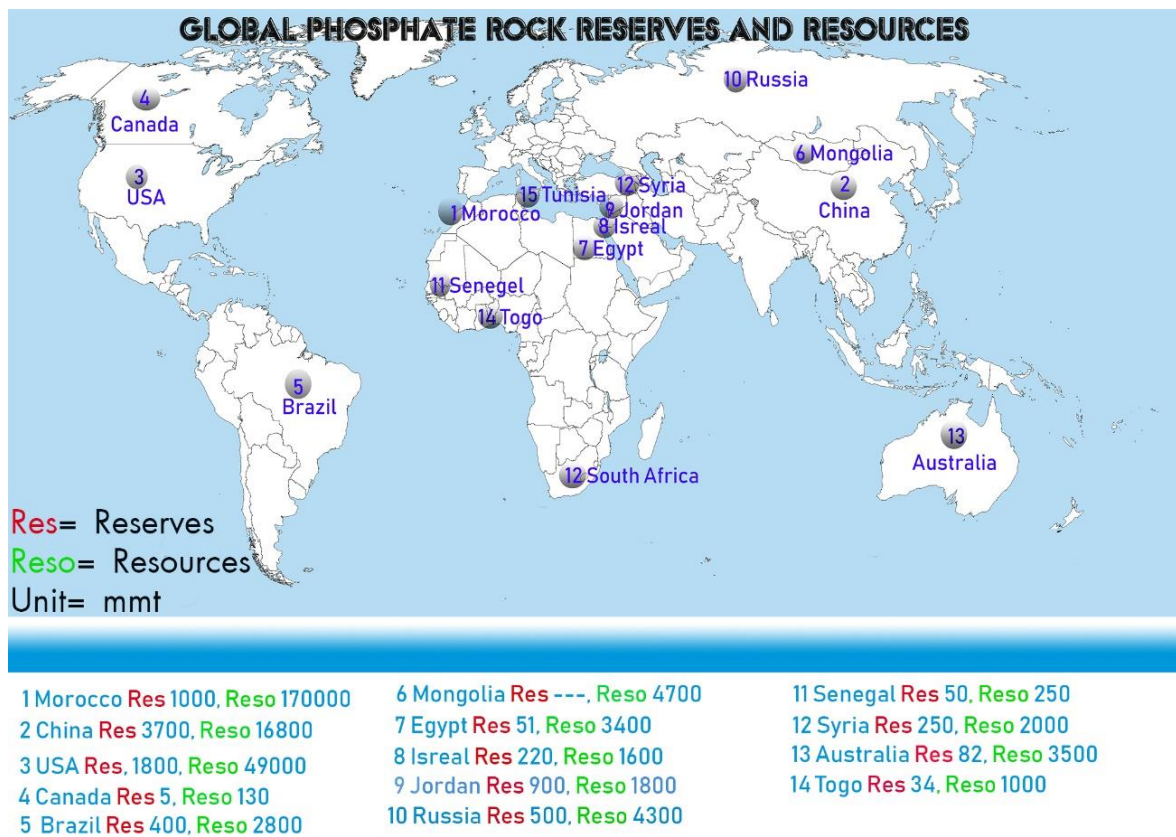
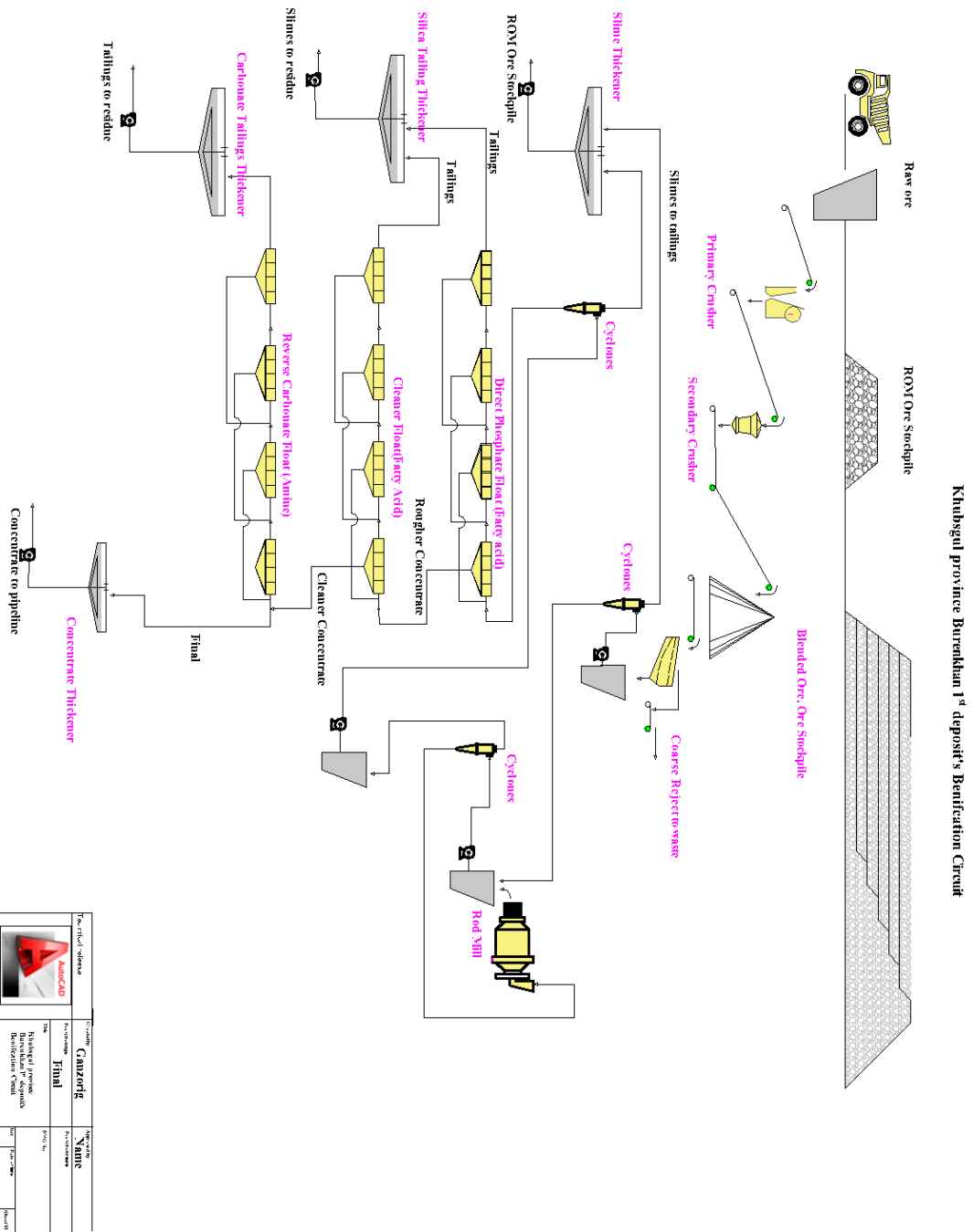


Figure 2 Global phosphate rock reserves and resources

3.3 Mining and processing technology of phosphate resources

Two types of phosphate rock mining methods can be used depending on their vertical meter (vm) and geometry. The majority of the global phosphate rock is removed through surface mining techniques, although some of them are extracted by underground methods. Surface mining can take many forms. It may be open pit or strip mining and may range from manual to highly mechanized removal methods. The selection of the processing techniques relies on the type of phosphate minerals existing in the ore as well as associated gangue minerals (5). The cheapest beneficiation techniques are crushing, screening or scrubbing, and de-sliming. The main gangue materials are hard siliceous material, silicates or clayey material. If the rock contained quartz, chalcedony or different forms of silica, then we should upgrade by using gravity or electrostatic techniques. The main conventional concentrating technique is froth flotation. This technique is more suitable for quartz, chalcedony, and silica contained phosphate rock minerals (5).

Figure 3 Phosphate rock, processing plant flowsheet



Project Name	Khubsugul province Buretkhan 1 st deposit's Benefication Circuit
Client	GAZNEFT
Contract No.	Final
Scale	30000
Project No.	30000
Project Name	Khubsugul province Buretkhan 1 st deposit's Benefication Circuit
Project No.	30000

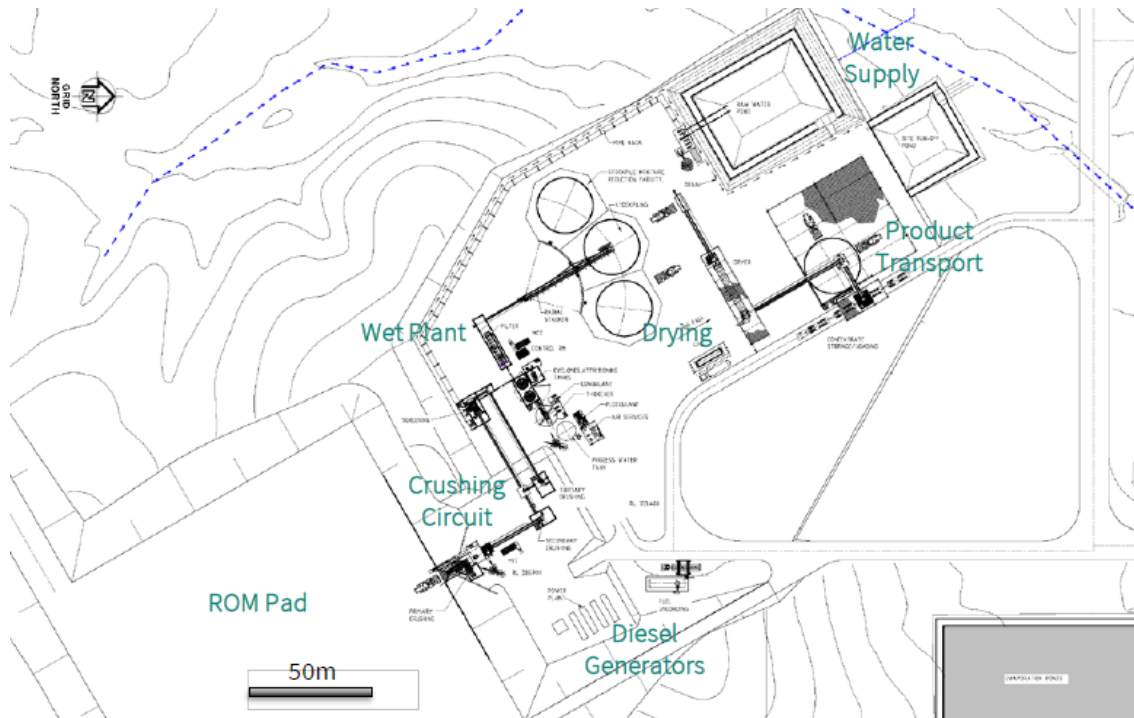


Figure 4 Beneficiation plant layout (39)

3.3.1 Phosphate rock mining techniques

Most phosphate rocks extracted through open pit mining techniques such as

- Dragline (Florida USA)

Phosphate draglines can hold from 45 to 65 cubic yards of material(4).

- Bucket wheel excavators (North Carolina, Togo)

Potash Corporation of Saskatchewan Phosphate Mine is in North Carolina, USA. It is considered to being the largest phosphate mining and chemical plant in the world. The manufacturing capacity is 6.6Mt of phosphate rock per year, 1.3Mt phosphoric acid per year, and 0.2Mt phosphate feed per year. In the mine, they have both bucket wheel excavators (BWEs) and draglines. BWEs utilized to remove the top 10 meters of overburden and convey it from the active mine field to the mined-out pit. The remaining deep ones withdraw 18-21 meters of overburden is withdraw with draglines to reach the ore body(5).

- Front end loader removal (Idaho, Phosphate hill Australia)

Southeastern Idaho is the richest phosphate deposit in the western United States and is second only to Florida in phosphate fertilizer production. A front end loader operates in long linear trenches, to remove the overburden of earth to get to sedimentary rocks. Smoky Canyon mine is operating with specially constructed oversized vehicles(6).

Ore Impurities and Beneficiation

- Initial removal of impurities from PR ore is called beneficiation
- Beneficiation of PR involves removal of materials such as sand, clay, carbonates, organics, and iron oxide.
- Beneficiation may involve
 - Screening (Wet or Dry)
 - Washing
 - Hydrocyclones
 - Calcination
 - Flotation
 - Magnets

Screening (Wet or dry) and washing

Washing and screening are processes to remove oversized material from the ore matrix ranging from 2 to 30cm. These removing processes contain clay slimes. But it is not economic to produce phosphate fertilizer from the clay slimes. This is due to, their relatively large energy consumption and the high prices of reagents in the next processes without any sufficient water source. Thus dry screening may be used(7).

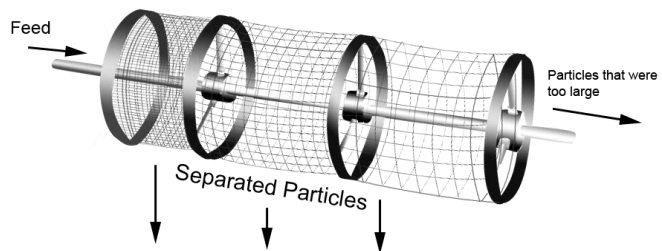


Figure 5 Washer and Trommel screen

3.3.2 Froth Flotation technology

Ore flotation

Froth flotation is a well-known process that selectively separates materials based on hydrophobic or hydrophilic materials. In this method, phosphate particles of interest are physically separated from a liquid phase due to the difference in the ability of air bubbles to selectively adhere to the surface of the particles, based upon their hydrophobicity. The hydrophobic particles and the air bubbles are attached and then carried to the surface, which is the effect of forming a froth flotation. The hydrophilic particles will stay in the liquid phase (9). Phosphate rocks are necessary to meet certain criteria in the beneficiation processing. It should be reduced the content of accessory minerals including quartz, chert, clay feldspar, mica, calcite, and dolomite. The phosphate ores to have content P_2O_5 content greater than 30%, a ratio of CaO/P_2O_5 lower than 1.6, MgO content less than 1%. Obviously, when it did not meet the requirement. It is necessary to remove unwanted materials(8).

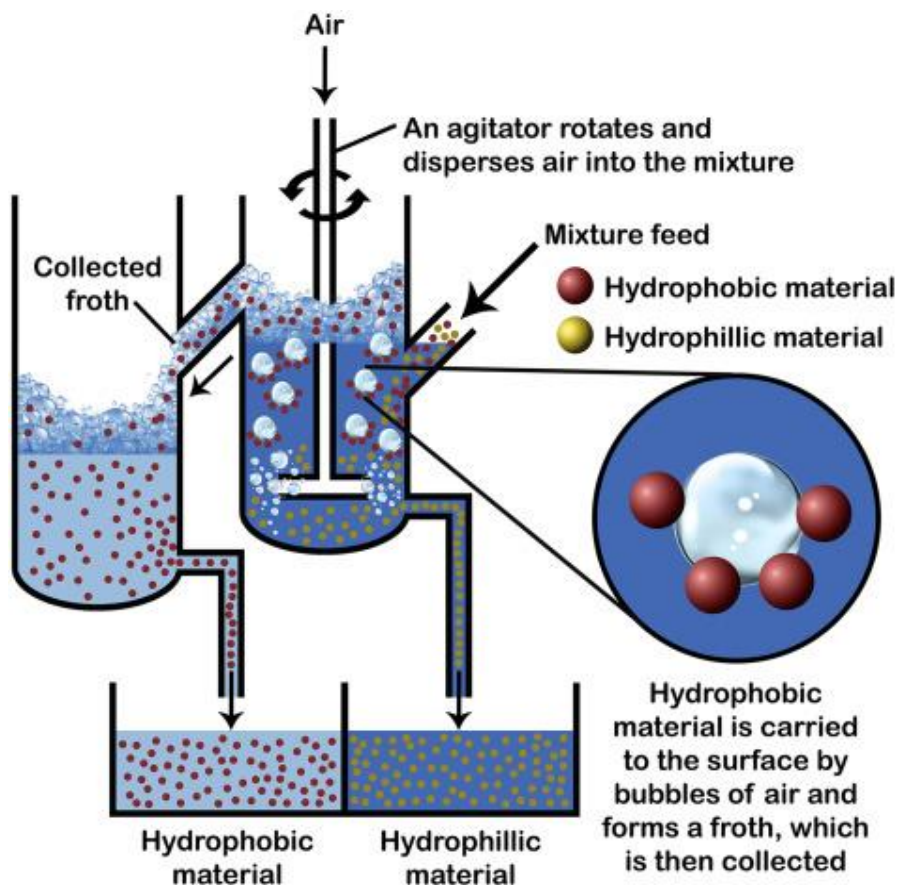


Figure 6 Process of Froth flotation

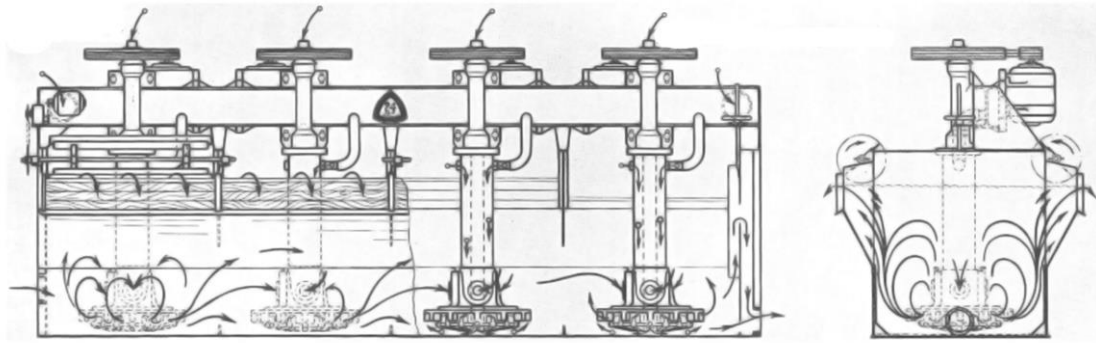


Figure 7 Typical phosphate rock flotation process (40)

Note: "Sub-A" phosphate type of flotation machine. Free-flow of pulp for fast-floating tonnage operation. The shaft assembly removed as one unit. Repeated pulp circulation is indicated to assure proper agitation and aeration. Supercharged air can be supplied down standpipe or down the hollow shaft, or both, as conditions require.

High carbonate content of phosphate deposits processed by the calcination and acid leaching methods are found in areas having low-cost energy and limited water source. Elgillani and Abouzerid (1993) explained the calcination process. It needed high capital cost, dolomitic phosphates difficult to calcinate, low quality of calcined product and high energy consumption.

On the other hand, the acid leaching method is applied when phosphate rocks contain a certain amount of carbonates. The carbonates can be easily leached away by any strong acid. Weak acids are not economical to use(8).

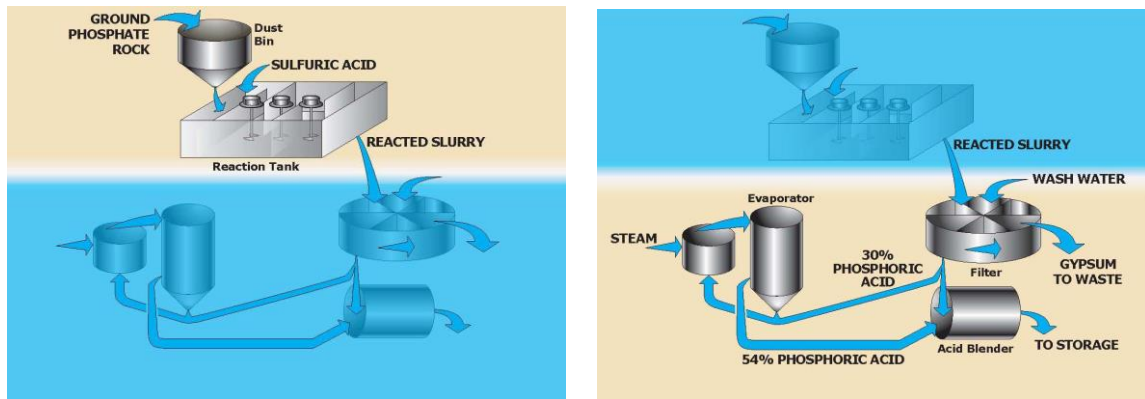


Figure 8 Wet process phosphoric acid production (7)

The production of phosphoric acid from the wet process involves three fundamental steps, a) reaction of PR and sulfuric acid to produce phosphoric acid and calcium sulfate (gypsum), b) separation and washing of the acid from the sulfate, and c) concentration of the acid (Fig.9 a). The acid produced in this process is ortho-phosphoric acid. Ortho-phosphoric acid can be further dehydrated to form polymers super phosphoric acid, which is used in the production of certain liquid phosphoric fertilizers called polyphosphates. Disposal of the gypsum by-product produced in the wet acid process can be problematic in some areas (Fig. 9 b).

Over 90% of global rock phosphates mined are directly shipped to the acidulation plant and mixed with sulfuric acid to make phosphoric acid. High-priced water soluble NPK fertilizer's chemical foundation is phosphoric acid. The main reason for converting phosphate rock to phosphoric acid are profit margins from selling high-end water-soluble fertilizer are much higher and it is made in a soluble form (increase reactivity). There are some difficulties related to the acidulation plant process. Each tone of acid created 3-6 tons of phosphogypsum (Fig. 9).



Figure 9 PG tailing bond (Mulberry fertilizer plant, Mosaic (up to 400 feet tall))

Flotation of phosphate ores

Sparingly soluble minerals commonly used in flotation namely, apatite ($\text{Ca}_5(\text{PO}_4)_3(\text{F}, \text{OH})$), fluorite CaF_2 , calcite (CaCO_3), scheelite (CaWO_4), magnesite (MgCO_3), and barite (BaSO_4) because these minerals are considered to be hydrophilic characteristic materials. Furthermore, oxide and silicate minerals have been successfully carried out by the froth flotation method. The various reagents indicate the effectiveness of the separation process. On the other side, some difficulties could occur caused by similar surface chemical materials approaches at the same time(8).

Types of reagents used in the froth flotation as example collectors, depressants, and auxiliary reagents in direct and reverse flotation of phosphate ores.

Polymers at the Mineral interfaces

Polymers adsorption behavior can occur at the mineral-water interface.

Nano-bubbles in Phosphate flotation

Coarse and ultrafine phosphate particles are difficult to process by froth flotation. For example, in the Florida phosphate plant, coarse phosphate particles (-1180+425 micrometer) sized recovery of the froth flotation. Coarse particles are much lower than the intermediate phosphate particles (-425+106 micrometer). It is common that tiny Nano-bubbles attach more readily depends on their lower ascending velocity, rebound velocity from the surface, and higher surface free energy to be satisfied. The utilization of Nano-bubbles increased P_2O_5 recovery and the flotation separation efficiency by up to 5 absolute percentage points(9).

Effect of Ca^{2+} , Mg^{2+} , PO_4^{3-} , and SO_4^{2-} on the Flotation of phosphate

This study is more likely related to wastewater recycling, before exploring the effect of phosphate ore floatation. We must consider several kinds of common ions such as Ca^{2+} , Mg^{2+} , PO_4^{3-} , and SO_4^{2-} . Flotation wastewater mainly originated from the dissolution of part of the ore ions Ca^{2+} and Mg^{2+} . On the other hand, PO_4^{3-} , and SO_4^{2-} come from sulfuric acid and phosphoric acid. Many experts and scholars have done many studies on the impact of ions on froth flotation.

The appropriate concentration and low concentration of Ca^{2+} would have a positive effect on flotation. However, a high concentration of Ca^{2+} would have a negative effect on flotation. Which means, it could reduce the separation efficiency and recovery and make the bubble more brittle. Mg^{2+} could worse impact on the phosphate forth flotation selectivity. PO_4^{3-} effected the concentration grade decrease and tailing grade increase. Finally, SO_4^{2-} considered to be the least effect on flotation when the concentration is not too high during the wastewater reusing(9).

3.3.3 Sulfuric acid

Fifty percent of the global sulfuric acid is used to make the phosphate fertilizers. The process for manufacturing sulfuric acid has four stages: 1) extraction, 2) conversion of sulfur to sulfur dioxide, 3) sulfur dioxide to sulfur trioxide and 4) sulfur trioxide to sulfuric acid(10).

1. Extraction of sulfur

The most important sulfur sources are oil, natural gas, and sulfur dioxide from metal refining. Many metal ores required to roast process, it leads to forming an oxide and sulfuric dioxide(11). Copper, nickel and zinc minerals occur in sulfide ore. Thirty-five percent of world sulfur obtained as sulfur dioxide from sulfide ore roasting(12).

For example: lead manufacture $2PbS(s) + 3O_2(g) \rightarrow 2PbO(s) + 2SO_2(g)$

2. Conversion of sulfur to sulfur dioxide

The sulfur melted by steam coils at 140 degree Celsius in brick-lined tanks. Then, it will spray into a furnace approximately 1030 degree Celsius. Due to the heat produced by the exothermic reaction. The sulfur dioxide and gas mixture passed through the hot gas filter, where any ash contaminations removed.

Chemical reaction: $S(s) + O_2(g) \rightarrow SO_2(g)$

3. Conversion of sulfur dioxide to sulfur trioxide

This reaction follows this formula: $2SO_2(g) + O_2(g) \rightarrow 2SO_3$. It has one cylindrical vessel which acts as a fixed bed reactor. It needs to be heated up to 430-degree Celsius.

4. Conversion of sulfur trioxide to sulfuric acid

At high temperature sulfur trioxide reacts with a water and the reaction can be expressed as: $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

3.2.4 Hydrometallurgy smelting

Erdmin Co. Ltd and Achit Ikht Co. Ltd are processing of copper ore and production of cathode copper by solvent extraction and electro winning process (SX/EW). Erdmin Co.Ltd built as a capacity of cathode copper production is 2880 ton per year. All sulfuric acid supplied from Russia and annual the usage of sulfuric acid is approximately 2500 ton per year(13). The production capacity of Achit Ikht is 10000 ton per year and 3.5 times bigger than Erdmin.

The Chinese Volant Industry and Central Engineering Institute for Nonferrous Metallurgical Industries (ENFI) developed a feasibility study for a Erdenet Concern LLC copper concentrate In 9 of July 2015(14).

Table 1 Project info in Erdenet Concern LLC, 200000 tons of sulfuric acid.

Financing	Investor to be selected through open bidding
Total required investment	US\$ 798 million
Capacity	Processing 530000 tons of copper concentrates annually
Key products	1200000 tons of cathode copper per annum
By products	170000 tons of sulfur and 200000 tons of sulfuric acid
Number of new jobs	759

3.3.5 Mechanochemical technology

The first time, G.Heinicke formulated a definition which has become accepted by the scientific community in 1984. After four years later, he summarized almost 100 years of development of mechanochemical. Mechanochemistry is a branch of chemistry in which mechanical energy is applied to materials causing chemical and physicochemical transformations regardless of the state of aggregation. In other words, it formulated as physicochemical transformations regardless of the state of aggregation(15).

In 1974, Juhasz formulated that mechanical-chemistry divided into two main processes. Primary processes contain the increase both of surface area and internal & surface energies but the decrease of coherent energy of solids which are related to the reactivity of the mineral. The secondary mechanical processes include aggregation, adsorption, and crystallization.

The important equipment used in the mechanical processes such as retch mills, tumbling mills string ball mills, vibratory mills, pin mills, rolling mills and planetary ball mills(15).

Natural apatite will not easily dissolve in the neutral and alkaline medium. If the solubility of the material increase, the grinding process is more useful than other expensive processes. G.Heinicke assumed that the best achievable dissolving apatite a maximum of 50%.

Mechanochemical gave us a chance to use lower than about 15 percent grade of phosphate ore (P_2O_5) or higher than 15 percent of phosphate ores deal with one of the environmentally friendly technology. But the produced activated fertilizer could not dissolve in water that is why it is considered to be environmentally friendly technology. The development of phosphorus mechanochemistry an opportunity to get 50-80% of the substance into easily soluble forms by using planetary and vibra-centrifugal mills(16)

Mechano-chemical technology of phosphate fertilizer production

Separation of grinding and activation processes used to achieve a high activation effect at low energy consumption. According to the author, the activation efficiency calculated by the 2% of the citric acid (CSP) and ammonium citrate solution of phosphate (CASP). During the experimental work, they have utilized the Burenkhan ore as a sample. To reach the achievement of the target, they chose the more suitable grinding devices by the categories of input capacity (kW), productive capacity (kg/h) and specific power consumption (kWh/kg). The results collected among the several grinder devices with higher efficiency and more economical equipment was the vibration centrifugal mill.



Figure 10 Phosphate fertilizer sample

Mr. J.Amgalan and their colleagues are chose the Burenkhan 1st deposit, and set the different time duration in planetary and vibra-centrifugal mills, and measured the activation of the material.

Their experiment was done with high speed “HAS-1” attritor of the Zegvar system. The process worked at 800RPM attritor speed and 2-liter grinding body volume, and in a continuous feed. The processing condition of 2% citric acid is more effective than ammonium citrate. Before processing phosphate activated flour, it has to be sealed in a waterproof container. According to the research, it is possible to produce activated phosphorus from this deposit’s phosphate rock.

4. Mongolian Large phosphate bearing basins and active mine

4.1 History (exploration)

In this territory, the joint Russian-Mongolian Scientific Research Geological and Paleontological Expeditions did enormous of explorations, research, and experiments. The general formula is $\text{Ca}_5(\text{PO}_4)_3|\text{F, OH, Cl}$. An apatite is a group of -phosphate

minerals, usually referring to hydroxyapatite, Fluor-apatite, and chlorapatite, with high concentrations of OH⁻, F⁻ and Cl⁻ ions(17).

The Sedimentary phosphate rocks found in Khubsgul and Zavkhan regions are geologically located on the right side of the Khubsgul Horidiliin Nuruu, north side of Darkhad Khotgor and covers southern Khubsgul Mountains.

In the 1970s to 1980s, there was an explosion in geological research, due to the communism (18). The stratigraphic classification of sedimentary rocks of Northern Mongolian divided into three regions. A meta-complexes (Baidrag, Buteel, and Bumbuger) and four sedimentary formations (Muren, Khug, Darkhad or Zavkhan, and Khubsgul) (19). The geologists discovered large phosphate deposits in Mongolia. For instance Khubsgul and Zavkhan-Phosphate bearing basins.

4.2 Zavkhan bearing basin

Precambrian glacial marine deposits (Ediacaran Maikhan Mountain formation) found in the Zavkhan region. As reported by the investigation of Neoproterozoic and Lower Cambrian strata of the Zavkhan basin are divided into six formations such as the Zavkhan (3000 m), Tsagaanolom (1900 m), Maikhanuul (220 m), Bayangol (720 - 1000 m), Salaanygol (600m) and Khaikhan(380) formations. The age of Zavkhan formation is about (732-777Ma) is represented by basaltic andesite in the lower and by felsic volcanic in the upper part of the section, with various explosive units, such as pyroclastic tuffs and ignimbrites and toward the top, arkosic and quartzose sandstones approach.

The mapping, it begins the end of the Khangain Nuruu, in other words, north side of Khasagjargaltain Nuruu. So that located the area between Zavkhan Gol and Bogdin Gol. The Zavkhan-bearing basin covers 24000 square kilometers area. Dorjnamjaa.D discovered 19 small-scale deposits and exhibitions in 2001. Furthermore, both of them considered utilizing in the fertilizer production. Those are Tsakhir Uul deposit and Ikhkhanan deposit(17). A structure of the Zavkhan deposit, the average slope is estimated as (30-40° to 56-60°), and monoclinally positioned.

Tsakhir Uul deposit

It has two layers which go approximately 10 kilometers. A higher concentration of phosphate rock (P₂O₅) ranged from 34%-36%(17). It is estimated as an over 465 thousand tons of Phosphate rock. The Taskhir Uul deposit situated in Yaruu soum(20).

Table 2 Zavkhan-phosphate bearing basin, 2 deposits, 6 exhibitions

No.	Phosphate: d - deposit, e - exhibition	Content		Thickness, m	Length, km	Resources, Mi tons
		lower	higher			
1	Ikh khanan d.	4.8	30	80-100	10.0-11.0	50
2	Alag davaa d.	5.2	36	5.1	9.0-10.0	30
3	Tsakhir Uul e.	6	34	8.0-20.0	9.0-10.0	-
4	Tsagaan Khairkhan e.	7.2	29.8	5.0-6.0	4.5-5	-
5	Bogd river e.	6.9	26	10.12	4.6-5.2	-
6	Baruun Arts e.	4.87	26.23	7.0-10.0	5.5-6.0	-
7	Zvvn Arts e.	7.1	26	5.0-7.0	6.7-7.0	-
8	Hewtee tsakhir e.	7.15	25.67	9.0-11.0	6-7.0	-

4.3 Khubsgul bearing basin

The Neoproterozoic-Cambrian sediments divided into two groups namely lower (Darkhat) and the upper (Khubsgul). Khubsgul phosphate deposit is the one of the Darkhat group represented by its uppermost Arasan formation (1500m) which involve predominantly of siliciclastics and volcanics-siliciclastics, for example: green, gray, brown, rare violet siltstone, sandstone, tuffaceous sandstone, and gravestone with some layers of grayish-cream pelitomorphic dolomite and lenses(1-2m) of gray thin-grained limestone with oncolites(21).

The Baikal Lake's consolidation has rifted in the Tuva-Mongolian massif formation of intracontinental (Darkhat-Khuvsgul, Sarkhoi, and others) rifts and the continental crust disintegrated. Phosphate rocks contain alternating structure fewer phosphate layers (1-3cm) and thinner lenticular dolomite laminae prevail in the western zone corresponding to the distal part of the sedimentation profile.

All trace elements contents are approximately equal and related to the Clarke level in both phosphate rock and dolomite layers. Rock phosphate of the western zone rapidly buried and exist of dolomite intercalations described by post sedimentary segregation. The eastern proximal zone is mostly by the so-called dolomitic phosphorites with variable-size irregular fragments

After many years of exploration resulted, in 1996, Bymbaa.J had estimated 3 billion tons of resources in Khubsgul phosphate bearing basin.

Figure 11 Geological scheme of the Khubsugul phosphate basin (I-Big Sayan fault, II-Argyingol fault, III-Khangav-Khentev fault (the earthquake sutre of 1905), 13-Marginal thrust framing Khubsugul basin: IV-Khugiingol, V-coastal, 14-Ancient fault in basement determinative block structure of basin)

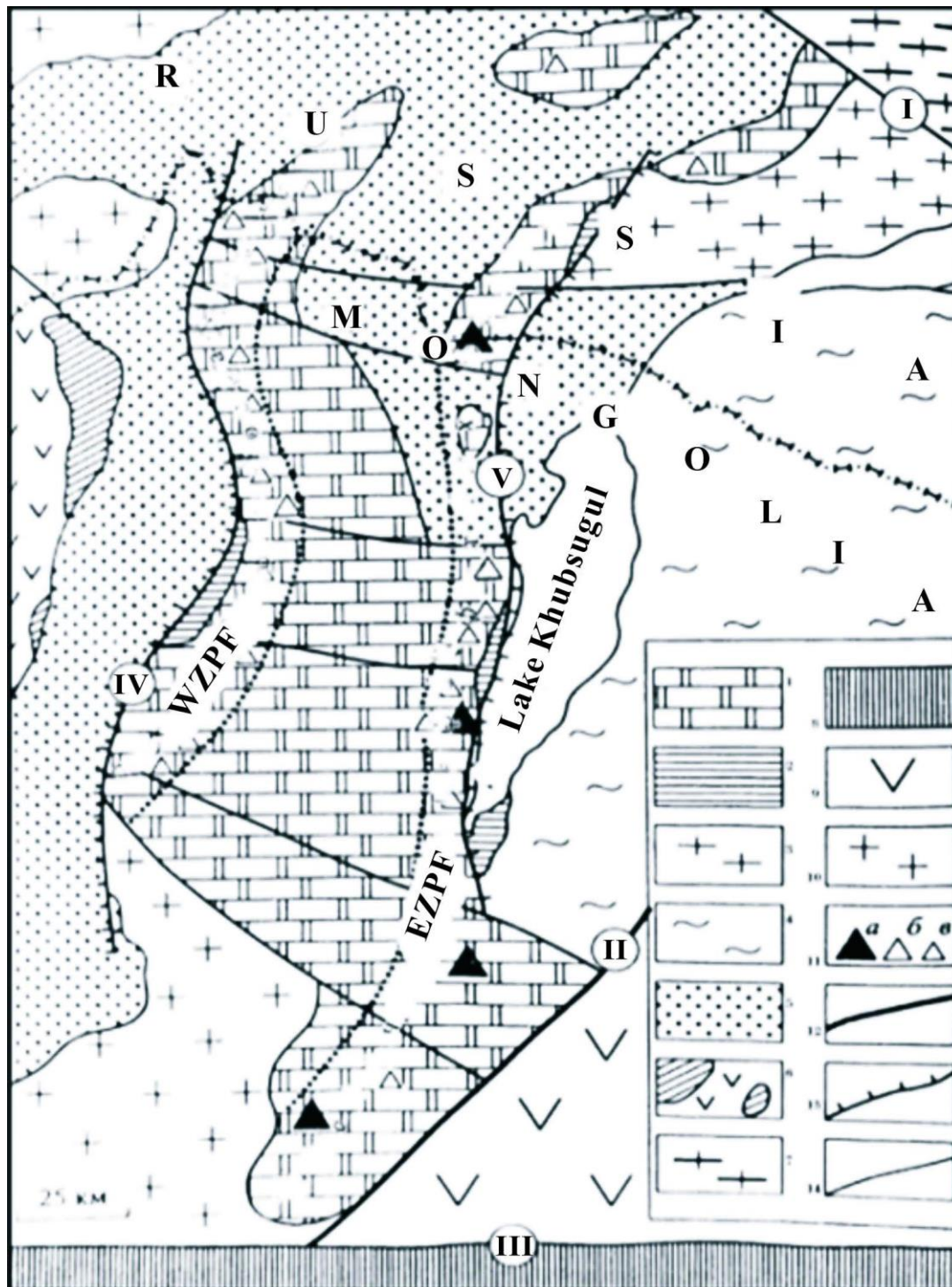


Table 3 Khubsgul-bearing basin, 8 deposits, 3 exhibitions.

No.	Phosphate deposit-d. exhibition-e.	Avg. ore content, resources			
		$C_{1+2}(P)$, millions of tones		$P_1 + P_2 + P_3(RS)$, million of tones	
		Mineral	C, %	Mineral	C, %
Khubsgul bearing basin(eastern)					
1	Khubsgul d.	250	19.6	903	18.7
2	Uliin davaani d.	-	-	150	22
3	Uhaa goliin d.	-	-	317	16
4	Berhem mountain d.	-	-	17.77	12.6
5	Manhan... mountain d.	28	17	56	17.1
6	Bvrenhkhan d.	205.57	23.1	113.2	20.5
7	Erhel lake d.	-	-	371	20.3
8	Svvl tolgoiin e.	-	-	50	15.-18
9	Dalangiin and others e.	-	-	19.4	21.7-27.3
Khubsgul bearing basin(western)					
1	Tsagaan lake d.	-	-	216	25
2	Hogorgo e.	-	-	1.5	12-21.0
3	Sum	483.57	-	2264.87	

4.3.1 Khubsgul deposit

The Khubsgul deposit is the biggest deposit among western Khubsgul-bearing basin. The mapping, along the west Khubsgul shore direction and it goes the north direction of Jankhain Nuruu , ends in Urandush Uul continuously 35-kilometer distance and it goes through the east Khoridol Saridagin Nuruu the mountains. The exact height above the ground level (AGL) is 2400m to 2600m, and the relative altitude is around 600m to 900m. From the petrography research, the ore is dark brown colored monophosphate, layered phosphate, Breccia, kind of oolite, fine particle, granular and consist of small grains. But the composition of Phosphorus ores depends on the ratio of several phosphate minerals, for instance: silicon, carbonate, and other minerals. The silicon consist of insoluble quartz, dolomite, calcite, and carbonate. The trace element in phosphate ore is Fluorine, Lead, Molybdenum, Vanadium, Nickel, Tin, Cobalt, Copper, Strontium, Zinc, Uranium, and Barium. The composition of phosphate (P_2O_5) higher concentration is 20-40%, lower concentration is 5-26%. Also, the resource is estimated at 1050 million tons of Phosphate rock, which is able to use production.

Table 4 Khubsgul deposit divided into three sections.

No.	Thickness of the phosphorus layers (m)	Content of P ₂ O ₅ (%)	Insoluble residue (%)
Ongkilog	5.6-15.4	15.8-27.2	6.5-14
Uran-dush	15-60	~ 21.4	14.9
Jankhai	3.5	26.1-28.2	20.1

4.3.2 Ongkilog lake phosphate mine

The phosphate deposit situated west of the Khubsgul Lake close to the Alag-Erdene soum. Ongkilog phosphate mine reserve an estimated 1.5 billion tons of ore. Due to some environmental issues, this mine was unable to produce fertilizers anymore (22).

4.3.3 Ukhaa Gol deposit

In 1970, Geologist A.V.Llyin discovered Ukhaa Gol deposit. The mapping, it is located east south of the Dornod Sayani Nuruu. This deposit situated north side of the Khubsgul deposit. The thickness of the phosphate rock (PR) is 1700m. Petrography of the deposit showed, 4 layers each layer has 4 to 5 meter of phosphate ore. The grade of phosphate rock ore is (P₂O₅) between 12.8% and 25%. A higher volume of insoluble is 23.9%. The net resource is 150million tons of phosphate ore with 22% of diphosphorus pentaoxide content.

4.3.4 Burenkhan deposit

Burenkhan deposit located northwest from Murun city about 20-22km, which means, it is at the edge of Khubsgul phosphate deposit. Many years of explorations resulted, it has estimated over 400million tons of phosphorite ore of rich and middle quality. Due to the tectonic movement, the phosphate rock (PR) has deformed as a synclinal fold. Preliminary Geological research has done in 1982 after that specific research has done in 1983. The phosphorus-containing several meters of thickness consists of 4 layers, the second order of 3rd and 4th layers had a width about 7.4 and 11.4 meters, 15.1 and 16.8 meters thickness, and continued 3700meter long, thickness and location are both of them have a stable layer. Depth is 125 to 200 meters from the surface. An average concentration of phosphate (P₂O₅) is 14.5 to 16.8 percent. More than 36 percent of resources are rich and rest of 64 percentage of PR has considered as a medium content (half rich). According to the Burenkhan deposit (see appendix. 1) that the conventional processing method is suspense floatation method. The Burenkhan deposit divided into

17 sections e.g. Burenkhan 1st deposit, Burenkhan 2nd deposit, Burenkhan 3rd deposit, and Burenkhan 4th deposit, etc. During 1965s and 1995s several geologist were did some research on those phosphate deposits. Their projects were embraced east, west and south Khubsgul's area about thirty thousands of square kilometer. In this region, they found around 40 phosphate ore deposits and exhibition. According to their investigation, in this region have 4.7 billion tons of phosphate resources(16).

4.4 Petrography of rock phosphate in Burenkhan first deposits

Thin-section petrography analysis is used to study of sedimentary structure, texture, framework grain composition, and type of distributions.

Table 5 Burenkhan 1st deposit, petrography analysis

	Burenkhan
Microscopic description	Phosphorus
Structure	Packed
Texture	Heavy
Granular size	0.4-5.6 mm

Composition of ore (Burenkhan)

85-90 percent of them consist of phosphate, and rest of them consist of quartz, chalcedony, aqueous ferrium and a pelite.

The result of the microscopic analysis: Isotropic properties, phosphate rock is made of dark brown colored substance, dispersed clay, organic matter in fine particle and granular. Phosphate rock substances made up 0.4 to 4.6mm course grained in between the pore chalcedony, aggregate and quartz cementing material size range between 0.2 to 0.4mm.



Figure 12 Burenkhan 1st deposit location



Figure 13 Phosphorite ore



Figure 14 Strata formed Burenkhan's ore



Figure 15 Burenkhan's ore

Figure 12-15 Burenkhan 1st deposit's location and phosphate ores

Mechanical and Physical characteristics

According to the Khubsgul Burenkhan first deposit passport, the density is 3.06g per cubic centimeters.

Humidity is the amount of water vapor contained in the material at a particular temperature. As reported by the phosphate first deposit passport, phosphorites humidity is expressed as 0.14%.

The water absorption rate is used to measure how much water is absorbed under a specified condition. It can be Vitreous (High density). As stated in this deposit passport (appendix. 1) the water absorption rate is 1.04 %.

Apatite is the name of a group of phosphate minerals. The index minerals are a hardness of five in the Mohs scale of mineral hardness. Based on the Burenkhan first deposit passport, the hardness of the phosphorites is 5-8 on the Mohs scale.

Table 6 Mineralogy

	Burenkhan deposit
Heavy fraction weight	37.67
Light fraction weight	128.65
Fraction weight	35.26
Magnetic fraction weight	0.01
Heavy fraction weight	2.40
Dust	23.40
Ilmenite	0.01
Monophosphate	34.76
Quartz	30.0
Carbonate	3.00
Clay	122.0

Table 7 Burenkhan 1st deposit, Major oxides in the phosphate ore samples (Institute of Chemistry and Chemical Technology, Central Geological Laboratory)

Number	CaO	P ₂ O ₅	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MgO	Na ₂ O	K ₂ O	CO ₂	F	Sum
Burenkhan	85.8	35.0	8.36	-	0.76	0.97	0.84	0.5	0.1	4.4	2.41	99.1

Burenkhan deposit Infrared spectrometer and X- ray structural analysis

Table 8 Burenkhan 1st deposit, phosphate ore's trace elements (g/ton)

Mo	Nb	Zr	Y	Rb	Pb	As	Zn	Cu	Cs	Sb	Sn	U	Th	Ba	Sr
11	3	70	100	20	10	17	55	75	91	208	112	10	14	11	1200

5. Economic evaluation of Mongolian phosphate deposits

5.1 Fertilizer market in Mongolia

Fertilizer consumption is used to measure how much of plant nutrients needed per unit of arable lands such as nitrogenous, potash, and phosphate fertilizers. But the traditional nutrients like animals plants manures are not included(23). In 2008, worldwide 333 thousands of square kilometers area were used to produce plants for biofuels and their coproducts. Biofuel production from food crops will increase by 170% by 2020 (24).

The Asia pacific fertilizer market was considered 887 billion U.S dollar in 2018, and China is the biggest user accounted for 52% of the total market(25). According to the CRU group, Russia exports 75 to 80% of its agro-chemical products(26).

The Mongolian market for fertilizer and pesticides is tiny compared to the other markets. It is highly regulated and under-controlled by official entities namely Ministry of Food, Agriculture and Light Industry, Ministry of Environment and Tourism and Ministry of Health. Furthermore, it is conducted with some institutions for instance General Agency for Specialized Inspection and Plant Protection and Research Institute. Mostly, fertilizers and pesticides imported from China, Russia and a little bit amount of them from European Union. These three ministries have estimated fertilizer products need and future demands. The usage of those products grows an average of 10% per year. Farmers who willing to improve their technical skills, and product amounts. Those farmers are complaining about the fertilizers are rarely available on the market. Generally, the small farmers buy chemical from a local seller or illegally imported from China's products. The main consumers of fertilizers and pesticides are big farmers, they are mostly producing wheat on more than 1000ha. In Mongolia wheat estimated more than 70% of the agriculture land, rapeseed more than 15%, fodder on 4.2% potato and other vegetables accounted rest of 4% of the land. The sum of annum necessary quantities of fertilizers assumed between 150000 and 200000Mt (27).

The Agriculture support Fund is the helpful actors for the Mongolian farmers. It provides some advisory service to farmers and to help some financial issues to buy fertilizers and pesticides. Fertilizer consumption in Mongolia was 38.278 kilograms per hectare of arable land in 2015(23).The highest data collected 44.815kg/ha in 2013 and the lowest record was 5.262 in 2005.

Mongolian fertilizer market major players are Gatsuurt XXK (importing fertilizers from Russia), Agriculture Support Fund (importing fertilizer from China), Mongolisch Ökologische Düngemittel GmbH (no produced fertilizer yet), Ensada Traktron XXK (participated Agriculture Fund in order to import fertilizers), Eco Green XXK (import

pesticides from Germany), Khiirev XXK (byproducts of the carbon extraction for the production of its fertilizer), Tsetsuuh trade (specialized in marketing lab-equipment, and agrochemicals(pesticides and fertilizers)), MSM(importing pesticides from Germany), and Shim XXK (importing fertilizer from Russia) (27).

5.2 Economic evaluation

The Mongolian geological prefeasibility study timeline from 1975-1999. From 1981-1982, technical and economical assessment done by the “Gosgorhimproject” branch of the Moscow Institute. Generally, mining economic evaluation calculation methods divided into a static and dynamic method. Static method contemplated to being old-fashioned. Nowadays An international economic assessment of deposits done by the dynamic method. To calculating economic data, we should learn how to calculate investment, revenues, Cost, operating profit, Net cash flow, interest and operating days.

Non-Metallic element prices

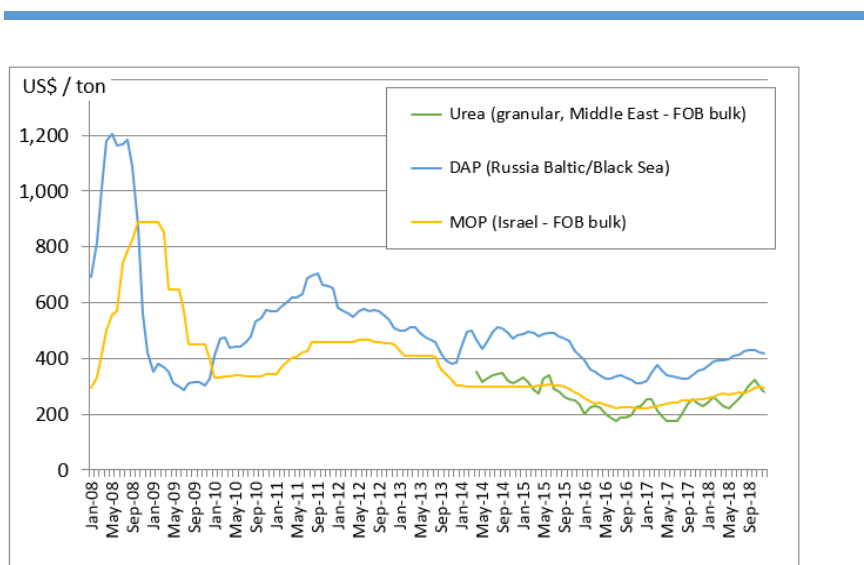
Major assumptions to be made in any economic evaluation is that of prices. Luckily, the commodity prices are steady at long-term like a weather chart. We should apply rules-of-thumb to determining the price:

- 1) Never ever choose a price peak, which is not last forever
- 2) To choose a price close to the manufacturer price.

Choice of Currency

According to the Investopedia, the U.S. Dollar considered to being the safest and the most tradable currency in the world. Choosing the right currency to mean that, it can eliminate to reduce the exchange rate influence.

Graph 1 Ten years-3 fertilizers UREA/DAP/MOP



Diammonium phosphate (DAP) and monoammonium phosphate prices remained stable in recent months. China DAP prices going down fractionally basis on firmer freight to 410 to 412 U.S dollar per ton. However, In this prefeasibility study, I assumed DAPR product a whole price is 185 U.S dollar per ton(28).

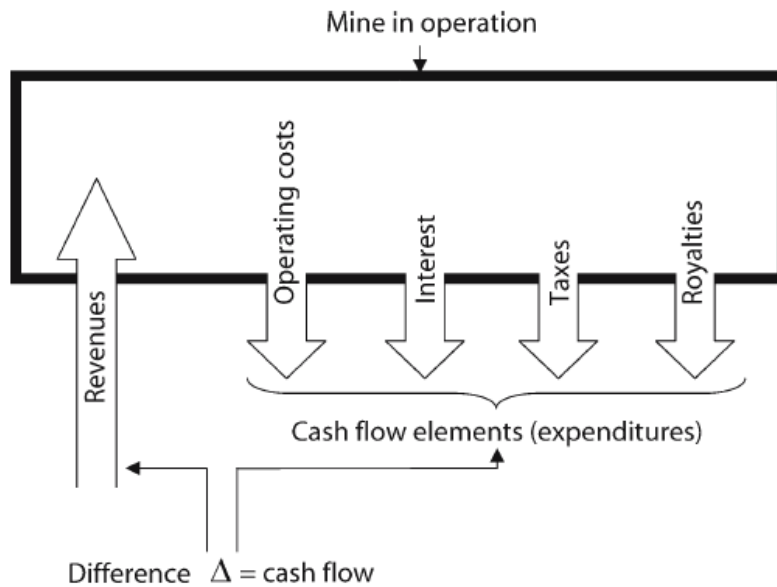


Figure 16 Explanation term of cash flow

The fig.4 illustrated that, how much money flow in and what money flows out of the system.

Rules-Of-Thumb for the lifetime of deposits

The companies want to reduce the productive life of mine. For a reason, that long-term operation may have risks. Prompted by the prices of fluctuations can be compensated and country risks. A high grade but small reserves as gold mines, were brought into production with much shorter lifetimes. However, low grade of Copper mine is different. They required considerable investment for infrastructure and should have to an operating lifetime of at least 20 to 25 years. Australian Mining Consulting (AMC) checked the open pit mines. The large open-pit mine vertical meter per annum of 30-35, while small pits may achieve 50-60vm/a, relying on the level of grade control and selectivity required(29). The optimal lifetime deposit can be calculated by the Taylor-formula.

Lifetime of Khubsgul first deposit should be:

$$\begin{aligned} \text{Burenkhan first deposit's life time } n \text{ (in years)} &\approx 6.5^4 \sqrt{\text{Tonnage(in million tonnes)}} \\ &= 6.5^4 \sqrt{(61.46)} = 18.19 \text{ years} \end{aligned}$$

Table 9 Lifetime of deposit (Taylor formula)

Expected tonnage (reserves in 106 t)	Medium lifetime (years)	Range of lifetime (years)	Average daily production (t/d)	Range of daily production
0.1	3.5	3-4.5	80	65-100
1	6.5	5.5-7.5	450	400-500
5	9.5	8-11.5	1500	1250-1800
10	11.5	9.5-14	2500	2100-3000
25	14	12.0-17	5000	4200-6000
50	17	14-21	8400	7000-10000
100	21	17-25	14000	11500-17000
250	26	22-31	27500	23000-32500
350	28	24-33	35000	30000-42000
500	31	26-37	46000	39000-55000
700	33	28-40	60000	50000-72000
1000	36	30-44	80000	65000-95000

From the graph, we can arrange an average daily production range from 7000 to 10000 tons per day.

Market barriers as a Determinant for a mine capacity

Taylor formula is not to cover market influence into consideration. For the phosphorus fertilizer market is limited and often dominated by a few buyers. The better way is to form a joint venture with producers who are already in the market.

Revenue = mineral grade*conversion factor* beneficiation recovery*Metal price*NSR=35*0.01*0.8*400*1*=112 U.S. \$/t

Open cut mining with beneficiation plant:

$I=A \times T^{0.6} = 700000 \times (8400)^{0.6} = 158 \text{ U.S. } \$ \text{ million (by using formula)}$

In the year 2005, the factor “A” was 700000 for open pit mines. Updating this factor is with a selection of typical base and non-metal or metal projects in the feasibility stage.

A-factor took from Raw Material Group data bank(29).

Table 10 Basic data

Total tonnage (tons)	61,46,000
Mine life time (years)	18
Annual tonnage (tons)	3,414,444
Daily capacity (t/d)	11,381

Table 11 Case I Calculation of Revenue (waste/ore ratio 2:1)

Commodity	Metal Grade	Conversation Factor	Percentage of the NSR for the mine	Recovery %	Metal Price	
P2O5 %	35.0	0.010	1	0.80	185.00	51.80
NSR (US\$/t)						51.80
- OPEX (US\$/t)						25.00
Profit						26.80

According to the beneficiation phosphate book(9), the flotation recovery range is from 81 to 90%.

Table 12 Case I calculation of OPEX, CAPEX (waste/ore ratio 2:1)

Mining, OP, w/o 2:1			Milling, Flotation 1 Product			Total
Opex	12.08	US\$/t	Opex	12.57	US\$/t	24.65
Capex	68,549,610	US\$	Capex	112,528,851	US\$	181,078,461

Table 13 Case II Calculation of Revenue (waste/ore ratio 4:1)

Commodity	Metal Grade	Conversation Factor	Percentage of the NSR for the mine	Recovery %	Metal Price	
P2O5 %	35.0	0.010	1	0.80	185.00	51.80
NSR (US\$/t)						51.80
- OPEX (US\$/t)						32.00
Profit						19.80

Table 14 Case II Calculation of CAPEX, OPEX (waste/ ore ratio 4:1)

Mining, OP, w/o 4:1			Milling, Flotation 1 Product			Total
Opex	19.68	US\$/t	Opex	12.57	US\$/t	32.24
Capex	118,240,808	US\$	Capex	112,528,851	US\$	230,769,659

Table 15 Case III Calculation of Revenue (waste/ore ratio 8:1)

Commodity	Metal Grade	Conversation Factor	Percentage of the NSR for the mine	Recovery %	Metal Price	
P205 %	35.0	0.010	1	0.80	185.00	51.80
NSR (US\$/t)						51.80
- Opex (US\$/t)						47.00
Profit						4.80

Table 16 Case III Calculation of OPEX, CAPEX (waste/ore ratio 8:1)

Mining, OP, w/o 8:1			Milling, Flotation 1 Product			Total
Opex	34.26	US\$/t	Opex	12.57	US\$/t	46.82
Capex	225,602,443	US\$	Capex	112,528,851	US\$	338,131,294

Table 17 Net present value (NPV) Burenkhan 1st deposit

Discount factor 10%	Annual Operating Profit	Value Factor	Investment	NPV
Burenkhan 1st (Best case I)	91507111	7.2497	181078461	482320643
Burenkhan 1st (Medium case II)	67606000	7.2497	230769659	259353559
Burenkhan 1st (worst case III)	16389333	7.2497	338131294	-219313545

Table 18 Payback period in different scenarios (Burenkhan 1st deposit)

Scenarios	Investment	Annual Operating Profit	Payback Period
Burenkhan 1st Best	181,078,461	91,507,111	2.0
Burenkhan 1st Medium	230,769,659	67,606,000	3.4
Burenkhan 1st Worst	338,131,294	16,389,333	20.6

Table 19 Compare different versions of projects

Company	Focus Ventures Ltd	Centrix Metal Limited	Itafos Farim	GrowMax Res corp	Ganzorig LLC
location	Sechura desert of northern Peru	Nord West Queensland	Guinea Bissau	Piura Region in Peru	Burenkhan ^{1st} dep
Potential reserve (Mt)	52.3	-	44	-	61.45
Production (Mt)	18.5	7.3	13.2	-	21.5
Yearly production (annum/Mt)	-	0.776	1.3	1	3
Production life time (year)	20	10	25	20	18.2
Net present value NPV (Million \$)	252.9	124-129	-	71 after tax (10%)	273
Grade (%)	24, 28	29	30	28	35
Payback (year)	6.6	3	-	6	0.8
Initial capital cost (million \$)	127	55-61	-	264	158
Project time (year)	2016	2018	2019	2020	2019

Note: In economic evolution, the capital cost does not need to consider.

5.3 Technical and economic assessment (TEA) of Burenkhan deposit in 1982

TEA developed in two variants according to the power of the mining and chemical complex. Variant I- annual production capacity of the plant for the extraction and processing of phosphate ores 6M/t, and variant II 12 M/t.

Open pit mine

Development of the field to provide an open way

- * 340 working days per year
- * 3 shifts per day
- * Shift duration 8 hour

5.4 Freight Costs

Phosphate fertilizers are typically transported by a combination of different transportation systems.

- ★ Heavy vehicle with load carrying capacity nearly 25 tones, which is considered to be high energy consumption is about 75ml/ (ton km).
- ★ Rail transportation is useful for long distance land transport, Major types of railway wagons capacity 70t per wagon. The moderate energy consumption is about 17ml/ (ton km).
- ★ Cargo ships that carry all of their material in container, cheap among other transportation systems. Only apply for a long distance transportation, energy consumption is about 7.5ml/ (ton km).
- ★ Slurry pipeline transportation manipulate solid particles through a pipeline. Which is designed with cost effectiveness for long distance and eco-friendly system(30).

5.5 Aspect of taxation

The major rate of the corporate income tax rate is 10% on taxable profits of up to MNT 3 billion per year and 25% on taxable profits to any excess of MNT 3 billion per year. Corporate income tax determined by deducting various expenses.

The companies may deduct from their gross income various expenditures incurred including the purchase of raw materials, fuel, salary, health and social insurance contributions, loan, interest, realized forex loss, marketing costs, subscribing to newspapers and magazines, insurance premium and fair wear and tear(31).

Table 20 Mongolian citizen's income and applicable taxes

Source of income	Applicable tax rate (%)
Dividends	10
Royalties	10
interest	10
Gambling, betting games and lotteries (net)	40
Sale of immovable property	2
Sale of rights (e.g. mining licenses, special activity licenses, and other rights granted by the authorized organizations for conducting specific activities)	30

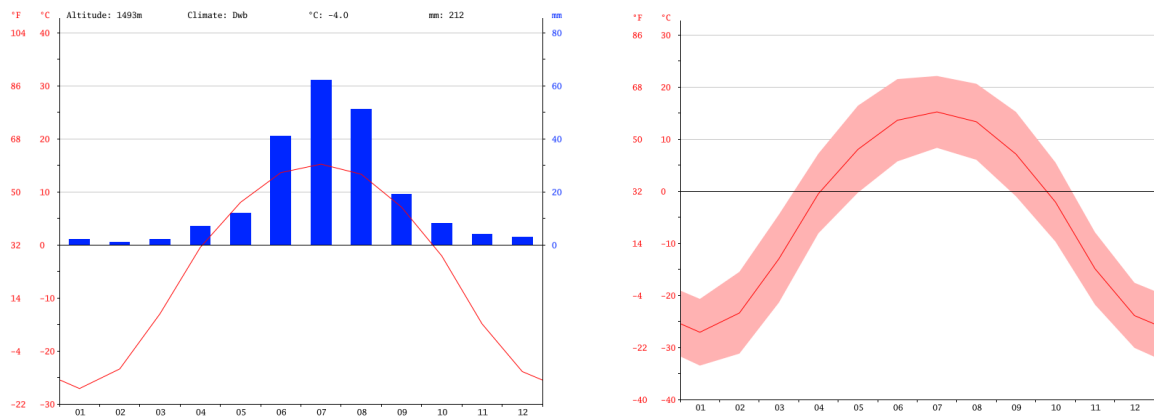
5.5 Mine ability of Burenkhan first phosphate deposit and country development

As I mentioned before, the Burenkhan first deposit, it situated northwest and 20-22km far from Murun city. This city connected the local electricity grid by 110kVolts of transmission lines. The city has 6.3MWatt of neighborhood transformer to steps down the voltage 110/35/6kVolt(32).

Delgermurun River, which is one of the well-known surface pure water sources in Mongolia. Also, the nearest pure water supply is Khubsgul Lake. The province consists of 36969 number of people, 19116 of them female(33).

In 2015, 71300 tourists visited in Khubsgul province and passed the Murun city. This city has 13 organization to support the either Mongolian or Murun province's economic. The organizations are Khubsgul-Dulaan XXK, Khubsgul Erchim XXK, Usnaak, Khubsgul Us Chandman, Urandush, etc. Those organizations provide electricity, drinking water, and clean up to the Murun city and nearby countries. In 2014, Murun city's unemployment rate was 7.9, a year later, it was going down until 5.4.

Here, the climate classified as a humid continental climate (Dwb) by the Köppen-Geiger scale. In Burenkhan, the average annual temperature is -4 degree Celsius. In July, the annual temperature and the annual perception reached the highest value (Graph 2). In January is on average the coldest month in any year, the average temperature is -27.1 degree Celsius(34).



Graph 2 Weather by months and the average temperature

5.6 Khubsgul Burenkhan deposit active mining licenses

Burenkhan phosphate deposit has several Mining licenses, for example, Топруонхэнцо ХХК МҮ-011823 (Burenkhan 9th deposit), МҮ-011824 (Burenkhan xxth deposit), and Сутайхэнцо ХХК МҮ-017398(Burenkhan 8th deposit) (35).

6 Environmental evaluation of Mongolian phosphate deposits

6.1 Environmental impacts of phosphate mine

The primary process of phosphate production is generating the waste rocks which either used as rock phosphorus fertilizer or is further processed to phosphoric acid for fertilizer manufacturing. The waste rocks considered to be a non-economic or sub-economic amount of apatite, and display the low concentration of phosphate, thus low radioactive and radon level. Sulfide content commonly found in phosphate production which may affect the generation of acid mine drainage, such waste material required to have direct monitoring. Waste rocks are usually stacked in piles near to the active mine. Some problematic issue a raised due to the, dumps required to monitor for erosional stability. If the wastes contain a significant amount of metals and metalloids (e.g. Ag, As, Cd, Cu, Mo), may lead to form a significant amount of metal and metalloids. In most cases, waste phosphate rocks are not harmful effect in the environment(36).

Mineral processing, it has several steps: firstly, to remove fine-grained rock and mineral particles as slimes; secondly, coarse-grained quartz sand particles as sand and finally, to concentrate the apatite. If we had organic-rich phosphate rock, we would heat before the processing in order to reduce the organic matter content to acceptable levels. The reject gangue materials contain calcite, dolomite, quartz, clays, and aluminum, iron oxides, and iron phosphates. During the phosphate beneficiation process, phosphatic clays and sands accumulate.

The greatest volume of PG generated during the acid production process around 3 to 6 tons of PG generated for every ton of phosphoric acid production. The production of phosphoric acid achieved pyro-metallurgy, and hydrometallurgy mineral processing methods. That's a so-called wet process, those mineral processing methods result in the generation of phosphoric acid, the process of the waters and PG waste. The familiar manufacturing process for phosphoric acid is established the use of sulfuric acid, which resulted production of PG.

Refer to their production process, two types of phosphoric acid can form. The result of the acid formations is dehydrated (gypsum: $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) or hemihydrate (basanite: $\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$). Generally, the high amount of calcium sulfate crystals occurred in PG. It also contains other reaction products (e.g. alkali fluorosilicates, fluorides), unreacted phosphate rocks, gangue minerals (e.g. quartz, phosphate, organic matter, and feldspar), heavy metals, metalloids and radionuclides.

Worldwide 100Mt of PG generated per year. Such a massive PG production creates major disposal, economic and environmental problems. The options for the disposal consist of discharging it into the sea, backing filling mined-out open pits, or stacking it in large heaps(36).

Potential hazards related to the PG are a failure of stacks, Atmospheric emission, water contamination, and radioactivity elements.

Process of water: the water commonly disposed of with the PG in a repository. Also, the mixture of the liquid contains a high amount of fluoride, sulfate, phosphate, ammonia, radionuclide, heavy metals and metalloid concentrations. Thus, PG dumps are containing very low pH level, which is a really hazardous substance, and it required to increase the pH level by using lime(36).

6.2 Impact on human health

Table 21 Degree of toxicity of elements in PR (37)

Associated elements found in phosphate rock	Degree of toxicity
Be, As , Cd, Hg, Ti, Ra	Extreme
F , Cl (Cl ₂), Cr (Cr ^{IV} , Cr ^{VI}), Ba , Gd, Yb, Pb	High
Li, Ni, Cu , Ga, Sn, Sb, Te, La, Ce, Pr, Nd, Sm, Tb, Ho, Bi, Th , U	Moderate
Ca , V, Mn, Fe , Zn , Ge, Mo, Lu	Low
Mg , S, Ca , Sc, Co, Se, Sr, Y , Zr, Nb, Ag, In, I, Dy, Eu, Er, Tm, Hf, Au	Negligible

The highlighted elements occurred in Burenkhan first deposit. This deposit contain extreme toxic element arsenic, high toxic elements such as fluorine, barium, and lead, the moderate toxic elements namely copper, tin, thorium, and uranium. The low toxic elements as well as calcium, iron, and zinc.

Table 22 Estimated collective does commitments (man) from atmospheric release of ²³⁸U and ²²⁶Ra from phosphate rock processing plant SICNG, Thessaloniki, Northern Greece (38)

No.	Organ or tissue	²³⁸ Ux10 ⁻⁹	²²⁶ Rax10 ⁻⁹
1	Lungs	1.957	0.152
2	Bone surfaces	0.0214	0.065
3	Red bone marrow	0.0014	0.0057
4	Liver	0.0000356	0.00076
5	Kidneys	0.0089	0.00076
6	Spleen	0.0000356	0.00076
7	G.I.track	0.000249	0.00114
8	Other soft tissues	0.0000356	0.00076

Grinding and drying operations resulted to increase airborne emissions. During the process, collective dose commitments can lead to a high concentration of ²³⁸U and ²²⁶Ra release to the atmosphere. Bone surfaces and lungs more suffered from those radioactive elements(37).

Table 23 Average phosphate rock and toxic metal concentration from different origin (nd-no data) (38)

Country	Deposit	Type	P ₂ O ₅	As	Cr	Pb	Hg	Cd	U	Sr
			(%)	mg/Kg						
Mongolia	Burenkhan	S	35	18.7	nd	11	nd	nd	11	1322.7
Algeria	Djebel Onk	S	28.3	4.5	174	3.0	190	22.5	25	2022
Morocco	Khouribga	S	32.6	13.4	200	10.3	855	15.1	87.7	150
	Youssoufia	S	31.2	9.2	255	14	120	29.2	97	nd
USA	North Florida	S	31.2	7	64.7	11.7	nd	6.14	80.7	nd
	Idaho	S	31.7	23.7	637	12.3	290	92.3	107	nd
	North Florida	S	29.9	11.2	158	8.33	233	38.2	65.3	nd
Russia	Russian Kola	I	39.5	3	14	4	42	<2.0	37	1600-2830
	Peninsula	I	35.6	10	nd	33	nd	1.25	27	1600-2830
Tunisia	Gafsa	S	29.3	4.5	144	4	nd	39.5	44	1925
Israel	Arad	S	32.4	5.5	130	2	129	14.3	150	nd
	Oron	S	33.6	8	107	1	128	5	99	nd
Syria	Khneifiss	S	31.9	4	140	6	28	3	75	1900

The heavy metals which had originated from the source of rock phosphate and then penetrate into the soil or water. Plants are well-known to absorb and translocate metals from vegetative tissues to grain and subsequently to the human body, it can result in diseases thereafter(37). At least 57 of the trace elements in rock phosphate which can impact on human health The Burenkhan first deposit contain 18.7mg/kg (Ar), 11mg/kg (Pb), 11mg/kg (U), and 1322.7mg/kg (Sr). On the other side, Burenkhan's deposit passport (appendix. 1), shows that phosphate rocks contained 1.22 to 39.10 percent of toxic elements. The deposit contains toxic elements such as Uranium, Thorium, Beryllium, Strontium, and Magnesium oxide.

6.3 Mine and processing waste management

Reprocessing aims to extract pure elements for instance sulfur can be extracted from sulfuric acid manufacturing, and calcium sulfate can utilize for building materials (e.g. gypsum plaster, boards, tiles, cement, hydraulic binder, glass, glass ceramic, and artificial marble)(36).

Use as construction materials

Phosphatic clay's fine particle is used to provide high strength of the concrete matrix at a smaller scale than the steel bars. It has similar characteristics as well as fly ash, silica fume, and blast furnace slag. Those materials are utilized in conventional concrete to get possible high ductility and long-term durability. A mixture of the phosphatic clay and concrete could improve the reinforcement of the concrete significantly(38).

Utilization of phosphogypsum (PG) in agriculture

PG contains several essential elements, for instance, calcium, sulfur, and phosphorus. Recent studies proved that usage of (PG) boosts root growth thus helping the plants to absorb nutrients and preventing crusting and reducing erosion. Also, it is well known for its capacity to improving soil structure by flocculation clays in the soil.

Usage of phosphogypsum (PG) in construction

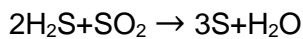
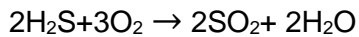
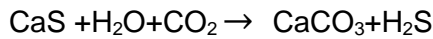
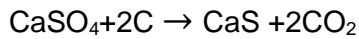
PG has found to be suitable for making wallboard or building materials. Utilization as a road base material has a great economic advance over conventional materials. By using PG as a road-building material can save the costs up to 80% within economic transportation distance.

Usage of phosphogypsum (PG) as a Chemical Raw Material

Utilization of PG as a chemical raw material: it is used raw material for recovery of sulfur and subsequent sulfuric acid manufacturing, as well as for ammonium sulfate. Both of

them utilization's are currently viable economically in some parts of the world. It has two routes depending on the market potential and prices for byproducts.

Route 1: it generates calcium carbonate as the main by-product through the following chemical reactions.



In the second process, lime (CaO) is generated as the major by-product by following reaction: $\text{CaSO}_4 + \text{C} \rightarrow \text{CaO} + \text{CO}_2 + \text{SO}_2$

The clinker from the kiln combines with gypsum to make cement. Nowadays, this type of processing factory is working in China. For example, The Wengfu Group of China built PG utilize factory with a capacity of 500000 tons of ammonium sulfate per year.

Uranium from Phosphoric Acid

According to the research, the most important development in uranium extraction from phosphoric acid is the advancement of the ion exchange technology. In the past few years, UrTek flourishing completed another round of pilot scale. There is two acid plant in the US by using PhosEnergy (ion exchange) technology.

Recovery of rare earth elements from phosphate and phosphoric acid

In recent years of studying result, the potential and viability of recovering rare earth elements from phosphate ore. But not only from phosphatic acid. Different streams such as the active mine, have beneficiation and acidulation streamed.

Improving phosphate recovery in the mine

The best recovery range in worldwide is within the lower than 80 percent. Selective mine effect that mine to bypass the difficult to process some of the portions. Majority loss of the recovery is due to the lack of instant information on the deposit as mining progresses. A continual research effort to develop laser-based on analytical tools for phosphate resulted that the dragline bucket can reduce phosphate loss significantly in the mining process (39).

7. Result and discussion

7.1 Environmentally

During the wet phosphoric acid production process will generate 3 to 6 tons of phosphogypsum (PG) to produce one ton of phosphoric fertilizer. In the PG stack, the toxic elements will accumulate and it will affect atmospheric emission, water contamination, and it will release radioactive radiation. Burenkhan first deposit contains extreme toxic element arsenic, high toxic elements such as fluorine, barium, and lead, as well as the moderate toxic elements namely copper, tin, thorium, and uranium. Compared to the different origin of phosphate mining's toxic metal concentrations, the content of arsenic is two times higher, lead is 0.18 times lower, while uranium²³⁸ is roughly six times lower, and strontium is again 0.27 times lower. Moreover, in this deposit does not contain problematic elements namely chromium, cadmium, and mercury. Compared to the other deposits, Burenkhan first deposit has a lower toxic contamination than other 14 deposits.

Effort to extract pure elements (e.g. sulfur) can be done by using sulfuric acid manufacturing; calcium sulfate can be utilized for building materials (e.g. gypsum plaster, boards, tiles, cement, hydraulic binder, glass, glass ceramic, and artificial marble). Even, uranium is suitable for extraction from phosphoric acid by the advancement of the ion exchange technology.

7.2 Economically

The U.S. Dollar considered to being the safest and the most tradable currency in the world. Choosing the right currency result in a reduction of the exchange rate influence.

China is the biggest user accounted for 52% of the total market. Mostly, Mongolian agro-chemicals (fertilizer and pesticide) are imported from China, Russia and minority of the imports come from European Union. The usage of agro-chemical products grows on average by 10% per year in Mongolia. Agro-chemicals are rarely available on the Mongolian market. The small farmers buy chemical from a local seller or bypass official sources by illegally importing from Chinese products. The sum of necessary quantities of the year fertilizers is assumed to be between 150000 and 200000Mt.

According to the beneficiation phosphate book(9), the flotation recovery range is between 81 to 90%. If the waste ore ratios are about 1:1, 2:1 and 4:1, then we could have a chance to mine the ore with a high profit. Otherwise, we cannot mine the deposit economically. The case I has the highest value of operating profit and net present value (NPV). From the payback period, we would say, period of two years and 3.4 years

payback period are mineable. In this calculation I did not include the wet acid plant's operating expenditure (OPEX) and capital expenditure (CAPEX). If we consider, the wet acid production plant then the NPV will go up. Compared to the different version of projects, Burenkhan first deposit have a high grade of phosphate rock (P_2O_5), low payback period, and high NPV. Those factors illustrate how economic to mine the ore. A shorter timeframe of the payback period will reduce country risks. Also, the easiest indicator to mine marketable is the concentration of P_2O_5 , which should be higher than 30%.

The major rate of the corporate income tax rate is 10% on taxable profit up to MNT 3 billion per year and 25% on taxable profits to any excess of MNT 3 billion per year. Corporate income tax is determined by deducting various expenses.

Rail transportation is useful for long distance land transport, major type of railway wagons capacity of 70t per wagon. Moderate energy consumption is about 17ml/ (ton km). Burenkhan first deposit is situated northwest and 20-22km far from Murun city. Murun city has 6.3MWatt of neighborhood transformer to steps down the voltage 110/35/6kVolt(32). The annual highest temperature reaches +22 degree Celsius and lowest temperature is -33 degree Celsius.

7.3 Production

Erdmin Co. Ltd and Achit Ikht Co. Ltd are the big cathode copper production plant in Mongolia. According to the, German – Mongolian Cooperation Project Sustainable Agriculture publication Erdmin Co. Ltd's all sulfuric acid charged from Russia. Erdmin and Achit Ikht requires nearly 10000 tons of sulfuric acid per year. Erdenet Concern LLC's have a project about copper smelter and the by products are 170000 tons of sulfur and 200000 tons of sulfuric acid per year.

8. Conclusion

The top manufacturers were the US, China, and Morocco, including Western Sahara. Those countries estimated over two-thirds of global production. The major value chain involves in S.A OCP (Morocco), Israel Chemicals Ltd (Israel), Jordan Phosphate Mines Company (Jordan), PhosAgro (Russia) and Yuntianhua Group (Chinese). Also, Brazil, Jordan, Egypt, and Tunisia are extracting phosphate rock derivatives. The worldwide phosphorus markets are classified on the basis of a type of resources, as an instance, sedimentary marine deposits, igneous & weathered rock, and biogenic, etc. The largest source for phosphate rocks are sedimentary marine deposits. Nearly, 75% of the global phosphate rocks are extracted from sedimentary marine deposits.

Sedimentary phosphate rocks can only be found in Khubsgul and Zavkhan territories. I summarized all those known deposits in Mongolia. Totally, there are 5.7 billion tons of phosphate rock involved in two bearing basins with an average 20% to 38% of phosphate rock composition P_2O_5 . While a rough worst-case estimation designated that global PR concentrate with 30% P_2O_5 phosphate rock marketable (PR-M) as the measuring unit.

Compared to the fifteen different origin of phosphate mining's toxic metal concentration, the Burenkhan first deposit content of arsenic is two times higher, lead is 0.18 times lower, while uranium is roughly six times lower, and strontium is again 0.27 times lower. The biggest environmental problem is related to the phosphogypsum (PG) stacks. PG stacks usually contains heavy metals and metalloids. Furthermore, gypsum stacks are covering a lot of areas and it requires monitoring to avoid failure. There is some utilization of PG stacks to make good quality products by using advanced technology.

Safest and most tradable currency is the U.S. dollar. Before we are starting projects, we must chose the right currency to avoid future exchange rate difference. Secondly, China is considered to be the biggest fertilizer market in the world. If we start to produce fertilizer, then we have only one big market. This is the reason other countries will not buy our products as an international fertilizer, because China is pushing our prices down. On the other side, Mongolia lacks of agro-chemical products on the market. Generally, the small farmers buy chemical from a local seller or buy-pass official by illegally importing from Chinese's products. The sum of necessary quantities of the year of phosphate fertilizer is assumed between to be between 87,500Mt.

From economical perspective, we would say, a period of two years payback (Case I) and 3.4 year payback period (Case II) are mineable. In this calculation I did not include the wet acid plant' operating expenditure (OPEX) and capital expenditure (CAPEX). If we

consider this point, the wet acid process then the NPV will go up. If the waste/ore ratio is about 1:1, 2:1 and 4:1, then we could have a chance to mine the ore with a high profit. Otherwise, we cannot mine the deposit economically. Compared to the different version of projects Burenkhan first deposit have a high grade of phosphate rock (P_2O_5), low payback period, and high NPV. Those factors illustrates how economic to mining the ore is. Also, the easiest international indicator to mine marketable is the concentration of P_2O_5 that should be higher than 30%.

The life time of Burenkhan first deposit is about 18.19 years and the annual operating profits are 91.5 (Case I), 67.6 (Case II) and 16.4 (Case III) million U.S. dollar. Burenkhan first deposit vertical meter (vm) is about 80 to 380. Therefore, it is more economic to extract ore by surface mining method. The cheapest beneficiation techniques are crushing, screening or scrubbing, and de-sliming. The main conventional concentrating technique is froth flotation because this technique is more suitable for quartz, chalcedony, and silica containing phosphate rock minerals. The hardness of the phosphorites is 5-8 in Mohs scale. Therefore, discontinued mining method is more suitable.

Mr. Amgalan.J and their colleagues have chosen the Burenkhan first deposit, and did some experiments in planetary and vibra-centrifugal mills, and measured the activation of the Khubsgul phosphate. According to this research, it is possible to produce activated phosphorus from this phosphate rock deposit.

Phosphate concentrate does not require wet acid production. If we want to produce the phosphate fertilizer, then we would need sulfuric acid. Producing sulfuric acid from sulfide ores copper, nickel and zinc mineral will give us economic advantages. For that, the option to gain economic advance is co-operate with Erdenet Concern LLC's, a project of copper smelter.

In summary, Burenkhan first deposit have the potential to produce fertilizer from phosphate rock. If this deposit is co-operate with Erdenet Concern LLC's then, Mongolian economy will have a chance to get stronger. From an environmental point of view, in this deposit, toxic elements are in really low concentrations compared to the different origin of deposits. From an economical point of view, if the waste/ore ratio is lower than 4:1, it still has a chance to be profitably extracted. In the future, this mine will completely provide Mongolian phosphate fertilizer market by itself.

9. Acknowledgement

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11. Appendixes.

Appendix 1 Khubsgul first deposit passport (page. 1)

Загвар. 9

Металл бус ашигт малтмалын ордын паспорт

Дугаар:	0688	Ордын нэр:	Бүрэнхаан
Жинхэнэ нэр:	1-р хэсэг	Туслах нэр:	
Хэрэглээний чиглэл:	агрохимийн түүхий эд	Үндсэн А.М:	фосфорит
Дагавар А.М:	фтор, г.ховор элемен	Муж, бус, район:	Хөвсгөлийн сав
Хүдрийн заншлаа:	Мөрөн-Хөвсгөлийн бүс	Нээсэн хүн:	Ю.Я.Савва
Нээсэн он:	1977	Гүйц, байгууллага:	Тува"Красноярскгеология"нэгдэл
Нээсэн тухай мэдээ:	Эрлийн ажлаар Бүрэн хааны ордод фосфоритын баялаг агуулагтай, ихээхэн зузаантай давхрага бүхий 19 бие даасан хэсгүүдийг илрүүлсэн байна.		
Аймаг:	Хөвсгөл	Сум:	Бүрэнтогтох
Номенклатур:	M-47-XXII	Үнэмлэхүй өндөр:	
Өргөрөг:	49 47 54	Уртраг:	99 58 24
Газар зүйн байрлал:	Мөрөн хотоос баруун хойш 35 км-т оршино.		
Региональ зураглал:	1980 онд 1:50000 ны масштабтай геологийн зураглал, мөн онд 1:25000 ны зураглал хийгдсэн ба 1981 онд агаарын геофизикийн 1:50000 ны масштабтай зураглал хийгджээ		
Эрлийн ажил:	1981-82 онуудад нарийвчилсан эрэл, эрэл-үнэлгээний ажил хийгджээ		
Толо, геофизик:	1:5000-ын масштабтай мензулийн зураглал болон 1:25000, 1:5000-ын гамма-спектрометрийн зураглал, цооногийн геофизик (каротажийн) судалгаа тус тус хийгдсэн. Мензулын 1:2000 ны масштабтай толо зураг 2,8 км.квад, талбайд хийсэн		
Хайгуулын аргачлал:	1982 онд урьдчилсан хайгуул, 1983 онд нарийвчилсан		
Атираат муж:	Хойд Монгол	Структур формаци:	Хөвсгөл, Жидийн синклинори
Төрөл:	синклинал	Нэр:	
Шалеуур:	геотектоник, литолог.	Геоморфологи:	Хүчтэй хэрчигдсэн дунд зэргийн үлпяхаг толгол
Гарал үүсэл:	Тунамал	Геологийн нас:	Венд-доод, дунд кембри
Хүдрийн нас:			

Эрэл хайгуулын ажлын үе шат, төрөл, хэмжээ, өртөг :

Гүй. бай.	Ажлын үе шат	Эх. он	Дуус. он	Суваг(м ³)	Карьер (м ³)	Шурф (м)	Босоо малт.(м)	Хэв тээ (м)	Бүгд (м)	Багана т (т.м)	Цохилт.ө рөмдл. (т.м)	Бүгд (м)	Өр- төг мян. төг
Зөвлөлтий нарийвчилсан "Зарубежгеология" нэгдэл	нарийвчилсан хайгуул	1981	1984	26677.0	3548.0		12.8			17360.3		17360.3	3

Appendix 1 Khubsgul first deposit passport (page. 2)

<u>Агуулагч чулуулагийн төрөл, байрлал, нас :</u>								
Чулуулагийн нэр:	Байрлал:	Нас:						
шохойн чулуу, доломит, цахиур		Венд-кембри						
Хүдэр хавийн өөрч:	Шохойн чулуу. Энэ нь тектоник хөдөлгөөний үр дүнд синклиналь атираажилд орсон байна. Ялангуяа дэвсгэр болж буй чулуулаг нь их хэмжээгээр занаржиж бутарсан байна.							
Хувирал:	Хүдэр нь гүнээдээ цахиуржих процесст автагдсан байна.							
Үйлдвэрлэлийн бүс:	Бүрэнхааны ордын I хэсэгт фосфориттой зузаалгийг 2 үндсэн, 2 туслах давхрага болгон ангилсан байна.							
<u>Ашигт малтмалын үйлдвэрлэлийн чанартай биет :</u>								
Биет, бүлгийн нэр :	фосфорит	Биетийн тоо:	4					
Биетийн хэлбэр:	давхарга	Суналын чиг ...ээс ...хүртэл	уртраг 240°					
Голлох чиг (град):	110°-120°	Байрлалын онцлог :						
Урт(м) ..ээс.. хүртэл	3700.0	Дундаж урт :	3700.0					
Өргөн (м) ..ээс...хүртэл		Дундаж өргөн :						
Зузаан (м)..ээс ..хүртэл	236.00	Дундаж зузаан:						
Дээврийн хурдасны байрлах гүн :	25,00-250,00	Балансад эзлэх хувь	34.2					
Тектоник:	Үндсэн давхрага нь зарим хэсэгтээ хоосон чулуулагийн үеүүд болон мишилээр 5 хүртлэх тооны жижиг үеүүд болон хуваагдаж байна. Биетийн зуаан гадаргууд ба гүнд нилээд хувиралтай бөгөөд хэсгийн төв хэсэгт сунал нь зүүн урагш болон өөрчлөгдөж байрлалын элемент нь тогтворгүй болно. Фосфоритын зузаалаг нь олон тооны жижиг атираа флексур, тасралтат шилжилтэнд өртсөн байна. Хэсгийн баруун талд фосфоритын зузаалаг ба түүний дэвсгэр хурдасны тектоник зааг ажиглагдах бөгөөд сброс-надвиг төрлийн эвдрэлд орсон байна. Шилжилтийн хавтгай нь зүүн ба зүүн хойш 30-40°-аас 75-85° налуутай байна. Энэхүү тектоникийн эвдрэл нь лимонитжилт, дэвсгэр хурдасны ба диабазын дэл судал, дэвсгэр ба хучиж буй хурдасны өнцгийн үл нийцлэг зэрэг шинжээр тогтоогдсон байна.							
Үйлдвэрлэлийн бүс:	Фосфорит агуулсан зузаалаг нь 4 давхрагаас тогтох ба хоёрдугаар зэргийн гэгдэх 3.4-р давхрага 7.4 ба 11.4м өргөнтэй, 15.1 ба 16.8м зузаантайгаар 3700м орчим үргэлжлэх бөгөөд зузаан ба байрлал нь харьцангуй тогтвортой. Мөн олон тооны жижиг атираанд өртсөн байна. Гадаргуугаас 125-200м гүнд байрлана. P2O5-ын дундаж агуулга 14.6-16.8% хүрнэ.							
<u>Ашигт малтмалын физик, механикийн шинж :</u>								
Ашигт малтмал:	Хэрэглээ :	Шинж 1 :	Шинж 2 :	Температур (град)	Циклийн тоо	Хэмж. нэгж. Тоон үзүүлэлт		
фосфорит	агрохимийн түүхий эд		эзлэхүүн жин, нягт, чийгшилт, ус шингээлт, бат бэхийн			г/см.куб 2.9, 3.06, %, 0.14, 1.04, 5-8		
<u>Хүдэр дэх үндсэн ба дагалдах ашигт малтмалын агуулга :</u>								
Хүдэр :	Ашигт малтмал :	Үнэл-гээ	хэмж. нэгж	Балансын нөөцийн A+B+C1	Балансын нөөцийн C2	УНК баталсан A+B+C1	УНК баталсан C2	Судалсан гүн :
	Фосфорит	Агрохи мийн	%	B -24.18		B -24.18		50-370,0 м

Appendix 1 Khubsgul first deposit passport (page. 3)

Хортой хольцын агуулга :

Ашигт малтмал :	Хэрэглээ :	Хольц :	Хэмжих нэгж :	A+B+C1 балансын нөөцийн	Батлагдсан нөөцийн
фосфорит	Агрохимийн бүтээгдхүүн	U, Th, Be, Sr, MgO	%	1.22-39.10	

Ашигт малтмалын (хүдэр) мөхлөгийн агуулга :

Ашигт малтмал :	Хэрэглээ :	Фракц (мм) ..эс..хүртэл	Фракцийн агуулга (мм) :	Дундаж :
Фосфорит	эрдсийн бордоо	0,5-2,0	38.8-41.1	39.95

Химийн найрлага: Судалгааны явцад авсан бүх сорьцуудад химийн шинжилгээ хийж зөвхөн P2O5-ын агуулгыг тодорхойлжээ.

Ашигт малтмалын (хүдэр) бодисын найрлага :

Хүдэр	Эрдэс	Хэмжээ	Найрлага	Мөлгөржилт
Фосфоритын	псевдобрекчи, хэмхдэс фосфорит	2-8 см, 25 мм		сайн

Хүдрийн шинж: Хүдрийн нөөцийн 36 % нь фосфоритоор баян ба хагас баян, 64% нь дунд зэргийн агуулгатайд хамаарагдана.

Технологи: Шинжилгээний үр дүнд фосфорын бордоо үйлдвэрлэхэд тохирох баяжмал гарган авч болохыг тогтоосон. Баяжуулалтын оновчтой арга нь суспенз-флотацийн цогцолбор арга юм. Мөн Бүрэнхааны фосфорит нь шар фосфор гарган авахад тохиромжтой боловч урьдчилсан боловсруулалт шаардлагтай.

Жишг: 1.Захын агуулга P2O5-10% 2.Нөөцийн блок дахь үйлдвэрлэлийн хамгийн бага агуулга 16% 3. Давхрагын хамгийн бага зузаан ба кондицийн бус хүдэр буюу хоосон чулуулгийн хамгийн их зузаан 5м 4. Хортой хольцын блок дахь агуулга MgO-7.0%, CO2-20%, Fe2O3-1.3%, YU-30 хэтрэхгүй байна. 5. Хөрс хууалтын хязгаарын коэффициент 10м3м3.

Хүдэр, үндсэн ба дагалдагч ашигт малтмалын нөөц :

Ашигт малтмал :	Хэрэглээ :	Бал. бүр нэгж т:	хэмж А+В	Баланс С1	Баланс А+В+С1	Баланс С2	Баланс бус	олборло-сон хэм-жээ	УНК баталсан А+В+С1	С2	Үлдэг-дэл А+В+С1,
Фосфорит	агрохими йн бүтээгдх	сая. т	В-24.19	37.27	В+С1-61.46		С2+Р1-48.5		В+С1-61.5		

Найрлага: Фосфатын эрдсүүд-апатит, үл уусах үлдэгдэл-хальцедон, кварц, карбонат эрдсүүд-доломит, кальцит, хольц эрдсүүд-пирит, лимонит, серицит, улаг гялтгануур, шаврын эрдсүүд, органик бодис, акцессор эрдсүүд-рутил, сфен, гранат, шпинель, флогопит нар цөөн хувийг нь эзэлнэ.

Нөөцийн тухай: 1-р хэсэг нь нөөцийн хэмжээгээр бие даасан дунд зэргийн оргод хамаарах бөгөөд 1983 онд С1, С2 ба Р1 зэргээр 1984онд В, С1, С2, Р1 зэргээр нөөц бодсон. Нөөцийн тооцонд зусалтийн ба геологийн блокын аргуудыг хэрэглэн, P2O5-ын агуулгыг 8%, 10%, 12% байхаар 3 вариантаар боджээ. Ашигт малтмалыг ил аргаар олборлоход тохиромжтой бөгөөд карьерийн гүн 80-380м-т хэлбэлзэнэ. Далд аргаар олборлох нөөцийг 1280м-ийн гүнээр бодсон.

Уулын нөхцөл: Инженер геологийн нийлмэл нөхцөлтэй, чулуулаг нь петрографийн олон янзын найрлагтай, олон тооны тектоник хагарал тархсан, агуулгач чулуулаг нь хүчтэй ан цавшилд орсон байна. Орд дээр уулын ажил хийхэд силикозын аюултай бөгөөд ордын ан цавшилын бүсийн зузаан их байгаатай холбоотой.

Гидрогеологи: 80-230м гүнтэй карьер малтан ил аргаар олборлоход гидрогеологийн хувьд онцын хүндрэлгүй

Ашиглалтын тухай: Ил аргаар ашиглалт явуулахад тохиромжтой бөгөөд хэсэг бүрт явуулсан судалгааны ажлыг нарийвчилж, фосфорит агуулсан хоёрдугаар зэргийн биетүүдийг судлах шаардлагтай юм.

Appendix 1 Khubsgul first deposit passport (page. 4)

Хэтийн төлөв: Нөөцийг өсгөх хэтийн төлөв сайнтай.

Геологийн тайлан, бусад баримт бичиг :

Баримтын төрөл	Баримтын нэр:	Зохиогч:	Протокол	Хэвл. он	УГФ дугаар
тайлан	Манхан уулын ордын эрл-үнэлгээ ба Бүрэнхаан ордын нарийвчилсан хайгуул	П.В.Осокин, В.П.Арсентьев	1984.3.29. №58	1984	3973

Бүрт. хууд. зохиосон	Б.Алтанхуяа	Он сар	6/1/1994
Хянасан	С.Алтангэрэл	Он сар	6/20/1994
Санд оруулсан	Б.Бүжинлхам	Он сар	11/3/1995
Нэмэлт ба засвар хийсэн	С.Алтангэрэл	Он сар	3/12/2003

Appendix. 2 Mineralogy composition in majority phosphorites

Chemical composition of phosphorite representative in KPB and DZPB (mass %)																
Zavkhan Phosphate Basin (ZPB), Khubsgul Phosphate Basin (KPB)																
Deposit	CaO	P2O5	SiO2	TiO2	Al2O3	Fe2O3	MgO	Na2O	K2O	MnO	SO3	LT	H2O	CO2	F	
Ald	41.3	30	20.8	0.26	0.84	1.75	0.24	0.39	0.23	0.01	-	0.88	-	1.02	1.8	
Ald	31.1	23.67	39.2	0.1	0.96	1.62	0.58	0.12	0.33	0.17	0.1	2	0.05	0.41	0.27	
Ald	27.7	20.15	42.2	0.11	1.53	2.47	0.3	0.1	0.3	0.19	<0.1	2.24	0.17	<0.4	1.6	
TsU	31.8	25.35	37.8	0.1	0.86	1.26	0.49	0.14	0.32	0.07	0.1	1.78	0.14	0.4	0.5	
TsU	29.1	21.15	42.7	0.11	1.53	2.47	0.3	0.1	0.3	0.19	0.1	2.24	0.17	0.4	1.7	
TsU	27.2	20.7	48.6	0.05	0.06	0.94	0.3	0.19	0.37	0.05	0.1	1.1	0.11	1.23	0.2	
Bkh	53	39.1	0.85	-	0.32	1.05	0.3	0.29	0.29	-	-	-	-	0.6	2.9	
Bkh	40.6	32.6	23.46	0.07	0.8	0.43	0.3	0.22	0.2	0.03	0.1	1.4	0.09	1.13	0.09	
Bkh	45.5	32.16	10.93	0.05	0.05	1.98	0.3	0.04	0.14	0.07	0.1	5.54	0.02	5.24	0.12	

Deposit	Content of element-admixtures if phosphorites in KPB and ZPB (g/t)															
	Mn	Ni	Cu	Zn	As	Sr	V	Cr	Pb	Hg	Co	Cd	U	Th	Be	K
Khb	78	23.8	24	39	22.4	1660	26	47	14.3	0.27	12.8	1.6	32	2.8	2	1.186
Khb	700	95	57	80	10	450	150	100	20	-	23	-	20	11	2	1.26
Khb	880	100	15	10	8	900	40	9	3	-	100	-	10	-	2	-
Khb	980	175	15	1	7	600	10	90	3	-	40	-	1.5	-	3	-
Bkh	142	65.6	43	52	29	1068	55	52	11	0.32	35.7	2.5	28	4.8	3	1.643
Bkh	280	57	52	98	-	769	150	28	23	-	6.5	-	23	10	3	-

