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хамтын ажиллагаа
DEUTSCHE ZUSAMMENARBEIT

BGR Bundesanstalt für Geowissenschaften und Rohstoffe

Rare Earths of Mongolia: Evaluation of Market Opportunities for the Principal Deposits of Mongolia

Technical Report

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Contents

Glossary of terms

Basket price (in US$/kg):
The theoretical price that could be obtained for one kilogram of fully separated rare-earth oxides, containing rare-earth oxides in the same proportions as found in-situ within the deposit.

Concentrate:
A processing product containing the valuable ore mineral from which most of the waste material has been eliminated.

Critical rare earths
The US Department of Energy, in its '2011 Critical Materials Strategy' report, said provision of rare earth elements dysprosium, terbium, europium, neodymium and yttrium are already reaching "critical" levels of short-term supply, meaning supply issues could occur from now through 2025.

Cut-off grade:
The minimum mineral grade at which material can be economically mined and processed (used in the calculation of reserves).

Deposit:
According to the Mongolian Minerals Law (200), clause 4.1.8: means mineral concentration that has been formed on the surface or in the subsoil as a result of geological evolutionary processes, where the quality and proven reserve makes it feasible to economically mine the natural resource.

Feasibility Study:
A comprehensive study of a deposit in which all geological, engineering, operating, economic and other relevant factors are considered in sufficient detail that it could reasonably serve as the basis for a final decision by a financial institution to finance the development of the deposit for mineral production.

Grade:
The amount of mineral in each tonne of ore.

Leaching:
A method of extraction in which a solvent is passed through a mixture to remove some desired substance from it. Leaching is used to remove metals from their ores.

Mineral Reserve:

The economically mineable part of a Measured or Indicated Mineral Resource demonstrated by at least a pre-feasibility study. This study must include adequate information on mining, processing metallurgical, economic and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified. A Mineral Reserve includes allowances for dilution and losses that may occur when the material is mined.

Proved Mineral reserve:

An economically minable part of a Measured Mineral Resource which therefore holds the highest level of geological confidence. The deposit is also proved minable in terms of economic, mining, metallurgical, marketing, legal, social and governmental factors.

Probable Mineral Reserve:

The economically mineable part of an Indicated Mineral Resource, and in some circumstances a Measured Mineral Resource demonstrated by at least a pre-feasibility study. The pre-feasibility study must include adequate information on mining, processing, metallurgical, economic, and other relevant factors that demonstrate, at the time of reporting, that economic extraction can be justified.

Mineral Resource:

A concentration or occurrence of natural, solid, inorganic or fossilized organic material in or on the earth's crust in such form and quantity, and of such a grade or quality, that it has reasonable prospects for economic extraction. The location, quantity, grade, geological characteristics and continuity of a Mineral Resource are known, estimated or interpreted from specific geological evidence and knowledge.

Measured Mineral Resource:

That part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics are so well established that they can be estimated with confidence sufficient to allow the appropriate application of technical and economic parameters, and to support production planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration, sampling and testing information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough to confirm both geological and grade continuity.

Indicated Mineral Resources:
That part of a Mineral Resource for which quantity, grade or quality, densities, shape and physical characteristics can be estimated with a level of confidence sufficient to allow the appropriate application of technical and economic parameters, and to support mine planning and evaluation of the economic viability of the deposit. The estimate is based on detailed and reliable exploration and test information gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes that are spaced closely enough for geological and grade continuity to be reasonably assumed.

Inferred Mineral Resources:
That part of a Mineral Resource for which quantity and grade or quality can be estimated on the basis of geological evidence and limited sampling and reasonably assumed but not verified geological and grade continuity. The estimate is based on limited information and sampling gathered through appropriate techniques from locations such as outcrops, trenches, pits, workings and drill holes.

Mineral prospects (also: **mineral occurrence**)
A mineral prospect has the least level of confidence and refers to an occurrence of geological interest that may not be of economic value.

NI 43-101:
National Instrument 43-101 – Standards of Disclosure for Mineral Projects.

Ore:
Metal or mineral, or a combination of these, of sufficient value in terms of quality and quantity to enable it to be mined and processed at a profit.

Ore body:
An ore body may correspond to an ore deposit, but more often the deposit includes several ore bodies.

Placer:
A surface mineral deposit formed by the mechanical concentration of mineral particles from weathered debris.

Pre-feasibility study
A comprehensive study of the viability of a mineral project that has advanced to a stage where the mining method, in the case of underground mining, or the pit configuration, in the case of an open pit, has been established. It includes a financial analysis based on reasonable assumptions of technical, engineering, legal, operating, economic, social, and environmental factors, and the evaluation of other relevant factors which are sufficient for a Qualified Person, acting reasonably, to determine if all or part of the Mineral Resource may be classified as a Mineral Reserve.

Qualified Person
Means an individual who (a) is an engineer or geoscientist with at least five years of experience in mineral exploration, mine development or operation or mineral project assessment, or any combination of these; (b) has experience relevant to the subject matter of the mineral project and the technical report related thereto; and (c) is a member in good standing of a professional association as defined by NI 43-101 (According to CIM-Canadian Institute for Mining, Metallurgy and Petroleum; other national definitions may vary).

Recovery
Is a term used in process metallurgy to indicate the proportion of valuable material physically recovered in the processing of an ore. It is generally stated as a percentage of valuable metal in the ore that is recovered compared to the total valuable metal originally present in the ore.

Waste: ore ratio
The tonnage or volume of waste material which must be removed to allow the mining of one tonne of ore in an open pit; expressed as tonnes of waste to tonnes of ore. Not to be confused with overburden:ore ratio, where the overburden is given as volume (cubic yard or cubic metres, and the ore as tonnes).

Abbreviations used in this report

$	US$; Canadian or Australian $ are indicated as CDN$ or A$, respectively
Basket price	the theoretical price that could be obtained for one kilogram of fully separated rare-earth oxides, containing rare-earth oxides in the same proportions as found in-situ within the deposit; calculated in US$/kg
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
Capex	Capital expenditure
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
CoG	Cut-off grade
HREE	Heavy rare earth elements
IMRI	Integrated Mineral Resources Initiative
Ln	Lanthanides. Two definitions exist: a) Rare Earth Information Center (Ames, USA) defines the 15 chemical elements (Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium,Ytterbium, Lutetium) as “lanthanides”; 14 of these are tradable items because the element Promethium does not exist in nature in commercial quantities. b) The International Union of Pure and Applied Chemistry defines the 14 elements following lanthanum as “lanthanides” (excluding lanthanum). This study follows the broader use of the term ”lanthanides” as laid out by the Rare earth Information center (definition a) of above)
LoM	Life-of-mine
LREE	Light rare earth elements

MRAM	Mineral Resources Authority of Mongolia
MREE	Medium rare earth elements (sometime also middle rare earth elements)
Mt	Million tonnes (metric)
ppm	Parts per million; 10,000 ppm corresponds to 1 %
RE	Rare Earths (unspecific group name, used in singular and plural form). The RE group of chemical elements comprises the Lanthanides plus Yttrium: 16 chemical elements, 15 of which are tradable items because the Lanthanide element Promethium does not exist in nature in commercial quantities
REE	Rare earth elements; usage in mineral economics includes 15 REE plus Yttrium. This term is synonymous to rare earth metals, because the rare earth elements are all metals. Concentrations given as REE are calculated in ionic form.
REO	Rare earth elements, calculated as oxides
SEDAR	"System for Electronic Document Analysis and Retrieval" is the system used for electronically filing most securities related information with the Canadian securities regulatory authorities.
t	Metric tonne
TREE	Total rare earth elements
TREO	Total rare earth oxides (TREE calculated as oxides)
TREOY	Total rare earth oxides plus yttrium oxide

1 Objective of study

This technical report is a contribution to the Integrated Mineral Resources Initiative (IMRI) financed by BMZ. The Integrated Mineral Resources Initiative comprises three operative modules: a module carried out by GIZ together with the Mongolian Ministry for Economic Development (MED), a second module in which PTB (Physikalisch-Technische Bundesanstalt, which is the German National Metrology Institute) and MASM (Mongolian Agency for Standardization and Metrology) work together, and a third module which is implemented by BGR together with MRAM. The report has been prepared by the BGR/MRAM module with the aim of evaluating the opportunities for the major Mongolian RE occurrences (Khalzan Burged, Khotgor, Mushgai Khudag, Lugiin Gol) of moving up to the production phase.

2 Methodology

The authors thoroughly researched the public domain and the technical reports made available by companies for information on RE exploration projects worldwide. Information on global reserves, resources, supply and demand has been compiled from internal statistics maintained by BGR and from disclosures in the public domain.

Information on REE occurrences and deposits from Mongolia was extracted from the study prepared by MRAM and BGR in 2011[1] and the presentations given by GRAUPNER[2] and MUFF[3] during a REE Workshop organized by IMRI in Ulaanbaatar on January 17, 2012 . Because of restrictive geoinformation policy, no updated data on the Mongolian RE deposits could be obtained from MRAM.

The geological occurrence and morphology of ore deposits and the type of minerals which host the REE have a strong influence on the viability of an REE occurrence and the elasticity of the supply side. Therefore, the basics of REE occurrences, their extraction and processing are briefly explained in Chapter 3 “Basic concepts of ore, supply chain, technological use”.

The method applied to evaluate the Mongolian RE deposits is by peer comparison, because there is not enough concise data at hand to apply economic or technological evaluation methods.

In June 2012, a one week excursion was carried out by MRAM and BGR staff to the South Gobi to collect field information on the REE prospects of Khotgor and Mushgai Khudag. Selected samples were analysed by SEM (scattered electron microscopy) in the laboratories of BGR[4] with the objective of mapping the distribution of REE in the rock samples.

Units in this study are given in the metric system, if not otherwise indicated. Prices and costs are quoted in US$ if no other monetary unit is shown.

3 Basic concepts of ore, supply chain, technological use

A full mineral resources project cycle goes through the following stages:

1. Pre-exploration (study of literature, so-called “armchair geology”)
2. Early exploration (analysing surface grab-samples, mapping and trenching)
3. Exploration (preparing NI 43-101 report, metallurgical studies underway)
4. Economic evaluation (feasibility/bankable feasibility study)
5. Development (detailed metallurgical testing, acquiring permits, securing finances)
6. Construction (go-ahead decision is made, physical construction of mine and downstream facilities)
7. Production (mine, concentration and separation plants are operating. Saleable product is produced)
8. Rehabilitation and closure.

At the present time, there are only two major RE mines outside China in operation. These are the REE mine at Mountain Pass owned by Molycorp Corporation, and Mount Weld in Australia, operated by Lynas Corporation. Most experts in the RE sector agree that only a few of the many RE projects will eventually make it to the market. Therefore, most projects are frantically searching for financing and technical solutions for RE extraction to make an early entrance on the market.

Early movers have the best chance of securing financing for the costly investments. Forecasts predict a RE oversupply for most elements of the RE group in a few years from now.

Projected time limits to bring exploration projects into production have more often than not been delayed. The main reasons for the delays are difficulties in raising the large amount of capital needed; but also, permitting problems caused by environmental issues (mainly the handling of hazardous wastes) cause delays because almost all RE mineralisations are associated with radioactive minerals. Another reason for delays is the complicated elaboration of an efficient flow sheet for the concentration, chemical extraction and separation of the REE.

3.1 Definition of Rare Earths

There is no generally agreed definition on which chemical elements belong to the REE group. Chemists, metallurgists, commodity traders, miners and geologists apply definitions which depend on their specific interests. In 1968, UPAC (Union for Pure and Applied Chemistry) recommended that the term REE should refer to the elements scandium, yttrium, and the lanthanides group which consists of the elements lanthanum (La), cerium (Ce), praseodymium (Pr), neodymium (Nd), promethium (Pm), samarium (Sm), europium (Eu), gadolinium (Gd), terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Tm), ytterbium (Yb), and lutetium (Lu). But this usage has not been generally adopted.

This study follows the practise of the mining sector which often applies the term REE to the 15 elements of the lanthanide group, plus the element yttrium (Y). Although yttrium is strictly speaking not a REE, it is included because of its natural association with the lanthanides and similar physical and chemical properties. The lanthanide promethium (Pm, atomic number 61) does not exist in nature in tradable quantities, and therefore the REE comprise 15 chemical elements used in the high-technology industry.

The chemical symbols and atomic numbers of the 14 lanthanide elements and yttrium which are included in the REE in this study are shown in Table 1.

Name	Symbol	Atomic number	Atomic weight	Density	Valen-cy	Melting point (°C)	Boiling point (°C)	Main technological application		
Lantha-num	La	57	138.9	6.15	3	918	3464	Petroleum refining, high-index glass, flints, hydrogen storage, battery electrodes	LREE	
Cerium	Ce	58	140.12	6.77	3 or 4	798	3443	Catalytic converters, oxidizing agents, polishing powders, yellow glass/ ceramic, catalysts in self-cleaning ovens	LREE	
Praseo-dymium	Pr	59	140.98	6.64	3	931	3520	Magnets, lasers, green glass/ ceramics, flints, pollution control	LREE	
Neo-dymium	Nd	60	144.24	7.01	3	1021	3074	Magnets, lasers, violet glass/ ceramics, capacitors	LREE	
Prome-thium	Pm	61	145	7.26	3	1042	3000	Nuclear batteries	LREE	
Samari-um	Sm	62	150.4	7.52	3	1074	1794	Magnets, lasers, neutron capture, masers	LREE	MREE
Euro-pium	Eu	63	151.96	5.2	2 or 3	822	1527	Red/blue phosphors, lasers, fluorescent lamps, mercury vapour lamps	LREE	MREE
Gado-linium	Gd	64	157.25	7.9	3	1313	3273	Magnets, high-index glass, lasers, X-ray tubes, computer memory, neutron capture	LREE	MREE

table continued

Name	Symbol	Atomic number	Atomic weight	Density	Valen-cy	Melting point (ºC)	Boiling point (ºC)	Main technological application		
Terbium	Tb	65	158.93	8.23	3	1356	3230	Green phosphors, lasers, fluorescent lamps	HREE	
Dyspro-sium	Dy	66	162.5	8.55	3	1412	2567	Magnets, lasers		
Hol-mium	Ho	67	194.93	8.8	3	1474	2700	Lasers		
Erbium	Er	68	167.26	9.1	3	1529	2868	Lasers (for communications), vanadium steels		
Thulium	Tm	69	168.93	9.34	3	1545	1950	Electron beam tubes, medical imaging systems (X-ray detection)		
Ytter-bium	Yb	70	173.04	7	3	819	1196	Infrared lasers, electrical stress gauges, reducing agent		
Lutetium	Lu	71	174.97	9.84	3	1663	3402	Scintillation counters		
Yttrium	Y	39	88.91	4.47	3	1522	3338	Automotive use, microwave communications, lasers		

Table 1: Physical properties and main technological uses of REE. Some authorities include the chemical element scandium in the RE group.

The REE are often subdivided into three groups, namely the LREE, HREE and MREE (see Table 1). However, not all researchers agree on where to separate the HREE from the LREE. Chemists and physicist tend to use similarities in the atomic structures to form the groups, namely their electronic structure. Those REE which have paired 4f electrons, namely terbium (Tb), dysprosium (Dy), holmium (Ho), erbium (Er), thulium (Th), ytterbium (Yb) and lutetium (Lu) are often included in the HREE group. Samarium, europium and gadolinium are the MREE, while the remaining

REE are the so-called LREE. By the way, this definition of the MREEs is the same one that the Chinese authorities use when talking about the export quotas allocated to light, medium and heavy rare earths.

However, there are many in the RE field who include the elements from lanthanum to neodymium in the LREE group and samarium to terbium plus yttrium in the HREE group.

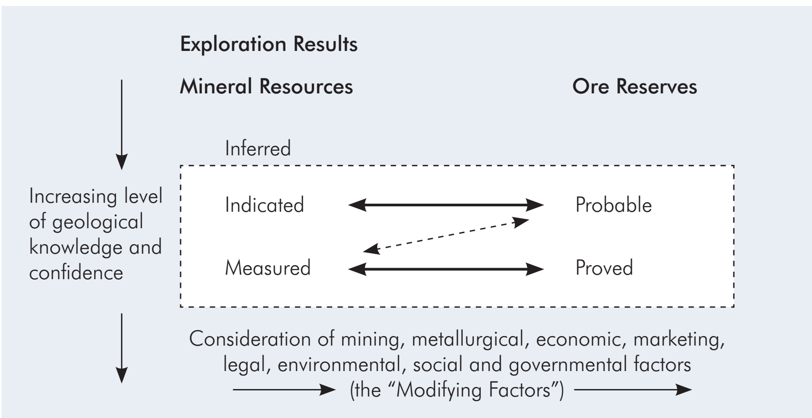
Although industrial demand for REE is relatively small in tonnage terms, they are essential for a diverse and expanding array of high-technology applications. REE-containing magnets, metal alloys for batteries and light-weight structures, and phosphors are essential for many current and emerging alternative energy technologies, such as electric vehicles, energy-efficient lighting, and wind power.

3.2 Reporting of exploration results and ore mineral inventories

The concept of documenting mineral inventories

Since the harmonization of mineral resource and mineral reserve definitions by UN-ECE (United Nations Economic Commission for Europe) and CRIRSCO (Combined Mineral Reserves International Reporting Standards Committee), the internationally accepted classification of mineral resources and reserves follows the pattern outlined in Figure 1.

Figure 1. Reporting scheme for reporting mineral resources inventories (Exploration Results, Mineral Resources and Ore Reserves) according to JORC and the NI 43-101.



The system outlined in Figure 1 is recognized by the internationally important organizations (JORC - Australasia, SAMREC - South Africa, NI 43-101 - Canada, SEC - USA, and the IMM – UK). The system follows the logic that the level and intensity of geological investigation and "modifying factors" qualify and quantify mineralization. Modifying factors consider mining, metallurgical, economic, marketing, legal, environmental, social, and governmental conditions which demonstrate at the time of reporting that economic extraction is justified.

In Mongolia, ore inventories are reported to the authorities and the Professional Reserve Committee in a system which closely resembles the system used in the Russian Federation. The Russian resource/reserve reporting system is very different both in principle and in detail from the reporting codes used internationally (JORC, SAMREC, Canadian NI 43-101, USA SEC, and the IMM code).

A comparison of the Russian resources/reserves classification used by the Professional Resources Council and the international system is given because the resources of the Mongolian RE deposits shown in the deposit passports (Appendix 2) are recorded in the Russian system. Essentially, the Russian system divides mineral concentrations into seven categories, in three major groups, based on the level of exploration performed:

- fully explored reserves or resources (A, B, C1)
- evaluated reserves or resources (C2)
- prognostic resources (P1, P2, P3)

Reserves and resources that can be matched to the usual international categories are classified into five main classes designated by the symbols A, B, C1, C2 and P1.

A broad equivalence between the classifications may be presented as shown in Table 2.

Russian system	International reporting code, JORC, etc
A,B	Proved Reserve / Measured Resource
C1	Proved or Probable Reserve / Indicated Resource
C2	Probable reserve / Indicated Resource / Inferred Resource
P1	Inferred Resource
P2	Reconnaissance Mineral Resource (or UNFC code 334)
P3	no equivalent

Table 2: Comparison of international and Mongolian/Russian resources classification. According to HENLEY (2004)[5]

Reserves versus resources

Reserves are the basis for production planning and their tonnage varies with the commodity price and available mining and metallurgical technology (see modifying factors, Figure 1).

Reserve figures may be utilized to estimate the production time (not life time) of a mine. But for estimating future supply security and strategic considerations, resource figures should be used.

3.3 Classification of RE deposits and mining of RE ore

3.3.1 RE Minerals

About 95 % of all the world's RE resources occur in three minerals, which are bastnaesite, monazite and xenotime. Most present day production comes from bastnaesite, followed to a much smaller extent by monazite in second place. Another source for REE, mainly the HREE, are the "Ionic Clays". Ionic clays are actually an ore and not a mineral, but as there are no ionic clay occurrences in Mongolia, they are not treated in this study.

Bastnaesite is a fluorocarbonate mineral which carries mainly the LREE and hardly any thorium. Its chemical composition is $LREE(CO_3)F$. Bastnaesite contains from 70-74 % REO and it is the RE mineral of the carbonatite-hosted REE deposits.

Monazite is a phosphate mineral with a composition of $LREE(PO_4)$. It contains about 35-60 % REO and may carry a high content of thorium. Depending on the most common rare earth element in monazite, the mineral is designated as "monazite-Ce", "monazite-La", and so forth. Primary monazite occurs as an accessory mineral in igneous rocks and is the RE mineral in alkaline igneous complexes. It is very resistant to weathering and abrasion, and therefore it accumulates in placer deposits and beach sands.

The RE minerals xenotime and loparite should also be mentioned although they are presently of minor economic importance in REE production. Xenotime is a phosphate mineral (YPO_4, where Y may be replaced by HREE) and contains 52-67 % REO, mostly of the heavy RE group. Xenotime is a heavy mineral with a high resistance to weathering, and accumulates in black sands and placer deposits. Loparite ((LREE, Na, Ca) (Ti, Nb) O_3) is basically a niobium ore mineral which may carry 32-34 % REO.

Two more RE should be mentioned here because they are described in the studies on Mongolian RE deposits, although they are not of economic importance. These are:

Parisite with the chemical formula $Ca(Ce,La)_2(CO3)_3F_2$. It contains about 27 % La_2O_3 and 33.60 % Ce_2O_3; and synchysite with the chemical formula $CaY(CO_3)_2F$. It may contain about 42 % Y_2O_3.

3.3.2 RE deposits

The minerals of RE occur in a variety of geological environments. They may be found in rocks related to magmatic activity. RE accumulations formed in this way are called "primary deposits". Weathering and other surface processes may redistribute and concentrate the RE minerals occurring in primary deposits. Concentrations formed this way are called "secondary deposits". The mineral contents, chemical composition, and style of mineralization of RE deposits is strongly influenced by the way the deposit formed. Therefore, the primary and secondary mineral deposit classes are commonly further subdivided (see USGS[6], BGS[7] and many technical reports on REE deposits).

The Mongolian RE deposits investigated in this study are either associated with carbonatite rocks (Mushgai Khudag, Khotgor, Lugiin Gol), or an alkaline intrusive complex (Khalzan Burged).

New extraction technologies makes it feasible to mine deposits which are not REE deposits *sensu strictu*. In these deposits, the rare earths are only one of many components within a bouquet of other value-elements. Also, projects are looked at which, because of their low ore grade, have been ignored in the past. Examples are black shale deposits (Buckton, Canada; see Appendix 1) or bauxite deposits (Grande-Valée, Canada; see Appendix 1) for aluminium production. One unusual project investigates RE enrichments along a regional fault without evidence of magmatic origin (La Paz, USA; see Appendix 1).

Lately, uranium ore processing waste is being looked at as an RE resource. These "technogenic deposits" may contain recoverable RE contents and the raw material is available without spending money on mining. In cases where improperly disposed waste from former uranium mining or abandoned uranium mines left a hazardous heritage, re-processing of these waste piles and the proper disposal of the residue may even contribute to an environmental clean-up.

REE may be mined as main products (REE-only mine), as coupled products, or by-products. The differences between these production modes and the mine economic implications are outlined below in Table 3:

Mode of RE occurrence	Mine production costs	Reaction to demand changes
Main products:	Main product bears all mining costs	High price flexibility, production may be adapted to demand changes
Coupled products: RE occur in separate mineral(s) in the ore body; motivation of mining is main metal	Mining costs for the RE are a matter of internal company agreements or agreements between parent and subsidiary company	Limited price flexibility, complex steering of production and pricing
By-products: RE occur in very low concentration within main metal minerals	By-product bears no mining costs. The tailings or waste heaps of the main product are the "technogenic deposit" for the by-produced RE	No price flexibility, production may not respond even when price increases are very strong

Table 3: Production mode of RE

The paired occurrence of RE with other products has important implications on the reaction to demand changes. Mines which produce REE as by-products or coupled products may not react adequately to changes on the demand side. On the other hand, they are economically more robust in times of volatile REE prices because other minerals contribute more to the mine revenue than the RE.

3.3.3 Mining of RE ore

The economic viability of an ore deposit is also dependent on the mining method applied to extract the ore. The selection of a mining method depends on many parameters. Proximity to the surface and a low waste:ore ratio are strong criteria for open pit mining. Other parameters for the selection of mining methods are: morphology of the ore body (geometric outline and attitude); nature of the contact between ore and sterile host rock; internal distribution of ore grade within ore body (because of ore dilution); and geotechnical properties of ore and host rock.

Most RE deposits are mined in open pit operations. Open pit mining costs are, by and large, 1/3 of underground mining costs. However, underground mining is indicated when access to the ore body is not possible via the surface (e.g., ore body under a lake), the cost of overburden removal is too high, the ore occurs in small, tabular bodies, or when underground mining facilitates the storage of hazardous waste by paste backfilling.

The mining step in the RE supply chain is the least expensive operation. The mass of moved material (waste and ore) is low according to mining standards and most RE projects under investigation are based on 4,000 tonnes per day operations. Mining costs are treated in Chapter 4 "The production chain of RE: from ore to metal oxide".

Waste streams and hazards of RE ore processing

All the waste streams from mining and processing RE can create radioactive hazards because REE are naturally radioactive, mostly because of accessory thorium.

The disposal of radioactive substances is costly and prone to accidents and has caused much environmental damage and many permitting delays. Examples are:

- The LAMP (Lynas Advanced Material Plant) in Malaysia is behind schedule because of permitting delays for the tailings.
- Spillages of radioactive waste water caused the closure of the Mountain Pass mine and the former owner (Chevron) was engaged in a costly cleanup.
- From 1982 until 1992, Japan's Mitsubishi Chemical was involved in Malaysia's RE refinery. Now the site is one of Asia's largest radioactive waste cleanup sites and Mitsubishi is engaged in a $100 million cleanup.

- One of several reasons why China is lowering RE output is the huge ecological damage caused by RE production. With the intention of lowering the ecological damage caused by REE mining and processing, China eliminated the mining of "monazite-only" deposits in June 2012[8].

In Mongolia, the Minerals Law, the Environmental Law, and the "Law on Nuclear Energy" regulate environmental matters related to the mining and processing of rare earth elements.

The original exploration literature of the Russian geologists, and later exploration campaigns and field visits, show the presence of uranium and thorium. In fresh samples from Mushgai Khudag, the occurrence of the RE mineral monazite, which is a carrier of thorium, has been shown by GRAUPNER[4]. The fact that Gama-spectrometry is a common exploration tool in RE exploration, highlights the presence of radioactive minerals. For the Khalzan Burged deposit in western Mongolia, it was found[9] that the concentrations of thorium and uranium are correlated with the REE contents, that is, ore with higher grade contains higher levels of radioactive elements (see ELSNER et al. (2011)[1].

Despite the lack of detailed investigations on the presence of radioactive elements in the Mongolian RE deposits, it is beyond speculation that radioactive substances will accumulate in the waste stream. Whether the amount of radionuclides will reach a level which makes it necessary to separate the waste into "non-hazardous" and "hazardous" waste can be clarified once technological investigations are completed.

The presence of traces of sulfide minerals has been described in the carbonatite ores from Mushgai Khudag, Khotgor and Lugiin Gol, but acid mine drainage will be no problem. The acid generation potential is extremely low because of the neutralizing nature of the carbonate minerals.

The hazards related to the inhalation of dust containing radioactive isotopes of the uranium or thorium families are addressed by the Labor Safety Law and the Nuclear Energy Law.

4 The production chain of RE: from ore to metal oxide

Production steps

RE production is much more complicated than the production of well-known base and precious metals. This is because the individual rare earth elements, which are mined as a group, must be separated from each other.

It is beyond the scope of this study to provide a detailed description of the RE metallurgy, and therefore only a generic process chain of RE ore from a carbonatite deposit, to which for example Mushgai Khudag, Khotgor and Lugiin Gol of Mongolia belong, is outlined in Table 4.

The term "resource processing" spans the production steps from the physical separation of RE minerals from rock-forming minerals, chemical concentration and upgrading, cracking (dissolution) of the RE minerals, their extraction from the RE minerals, and the separation of the individual REE from the RE group. Years are spent on testing at a laboratory scale and pilot plant scale the most efficient and economic method to recover the RE from the ore. A survey of contemporary extractive metallurgy of RE is given by GUPTA and KRISHNAURTHY[10], and some companies developed their own proprietary methods which are confidential or covered by patents.

<table>
<tr><th colspan="2">Production step</th><th>Product</th></tr>
<tr><td colspan="2">Mining: Mining involves removing mineralized rock from the ground through open-pit or underground methods.</td><td>RE ore</td></tr>
<tr><td>Milling and beneficiation: this step grinds the ore and produces a concentrate of REE minerals by gravity, magnetic and flotation techniques. The rock is ground down to a powder with a grain size smaller than the grain size of the ore minerals. The finer grained the ore, the more costly the milling process.

The product of this step is a physical concentrate. Flotation alone may produce a concentrate of about 10 % REO, while a combination of all methods leads to a concentrate of about 60 %.

Carbonatite ores lend themselves to further "chemical upgrading" by dissolving the non-REE-bearing calcium and strontium carbonates. A physical RE concentrate of about 60 % REO can be upgraded to about 70 % REO. Subsequent calcination liberates the CO_2 in the carbonate minerals and produces a concentrate of about 85-90 % REO.</td><td rowspan="2">The entire process from beneficiation (preparing a mineral concentrate) to the production of a TREO concentrate is referred to as "processing"; most capex statements give lump figures for the entire "processing" stage only.</td><td>Physically and chemically enriched mineral concentrate.</td></tr>
<tr><td>Leaching of REE from RE minerals ("cracking"): It is important that the input concentrate is of high grade because the presence of other rock minerals will complicate the process and the reagent consumption is high if a large volume of non-pay minerals are dissolved in the hydromet step. A heated rotary kiln is used if thermal leaching is necessary. In many processing plants, this step involves the dissolution of the RE minerals in a carbonatite ore concentrate with sulphuric acid. Firstly, calcium, thorium and iron are precipitated from the RE solution, and subsequently the RE can be precipitated as RE carbonates.</td><td>Depending on the chemical process route, the product of this step is a liquid mixed RE chloride, fluorite, oxalate, sulfate or nitrate, or a solid RE carbonate. These are "intermediate products" for further processing on site or by contractors, but they are rarely a saleable product.</td></tr>
<tr><td colspan="2">Separation (hydrometallurgical process): The RE salt solution (liquid chloride) is separated into rare earth oxides of the individual elements. Separation methods are precipitation, solvent extraction (SX) or ion exchange (IX). Because the RE are so similar in their chemical behaviour, the separation steps have to be repeated many times in order to achieve a pure product consisting of one single REE.</td><td>Individual RE oxides (powder) are the first saleable REE products.

RE oxides are further processed to metals and alloys.</td></tr>
</table>

Table 4: Generic process chain of RE from carbonatite ores to metal oxides

4.1 Production costs and prices of RE

Cost estimates

Operating and capital expenditures may be collected from Technical Reports and Preliminary Economic Assessments (PEA) disclosed by many companies. The cost data used in this study have been collected from the public domain and technical reports filed with SEDAR. The sources of the data indicate an accuracy +/-30 % of their cited costs. For cost comparison, REE projects similar to the ones in Mongolia were chosen. Cost estimates for the final production step, that is the metal refining stage, are not included.

Operating expenditures (opex)
Operating costs for mining will vary through the life of mine, because of increasing total cycle time caused by the deepening of the pit. The data used are average life of the mine figures, without taking inflation into consideration. Processing costs depend on the quality of the ore and the ore grade. Low-grades and, fine-grained ores with complex intergrowths and mineral assemblages cause the highest operating costs.

By and large, costs for projects located in cold climate zones are higher than those located further south because of the construction of confined and thermally isolated working places, and constraints put on the efficiency of mechanical equipment.

Breaking down the opex to the production stages provides the figures given below:

a) Mining: Contributes 5 to 10 % of total opex. Energy costs (diesel) and maintenance (including spares) are major mining cost components.

The total cash operating costs for open pit mining range from 3 to 6 US$/t. For comparison: underground mining of tabular, steeply inclined ore bodies is about 15 US$/ tonne. Because of the climatic conditions, open pit mining costs for the Mongolian REE deposits will be close to 5 or 6 US$/t ore mined.

b) Processing: In most published cost estimates, the operating costs for the milling and beneficiation stages, leaching and separation steps are cumulated and published as “processing costs”. They cause up to 80 % of total opex. Chemical reagents are the most costly consumable in this step. Some sources indicate that 1/3 of the processing costs are caused in the milling and flotation unit, and 2/3 of the opex occur in the hydrometallurgy and precipitation facilities.

c) General & Administration, product transport, tailings operation account for the remaining opex. Several projects quote that about 10 % of total opex is caused by G&A.

Not included in the opex are costs for mine closure and remediation and the exploration costs outside of the mining license area.

Capital expenditures (capex)
The capital costs for RE mining and processing facilities are in the order of several hundred million US$. Due to the low tonnage mined per day, investments in the mining step are low and are about 5-15 % of total capex (including shipping and transport of the equipment to the site, plus initial stocks of spares).

Capital expenditures related to the processing of RE (concentrator plant, acid cracking plant, acid storage facilities) are above 1/3 of all the capital expenditures.

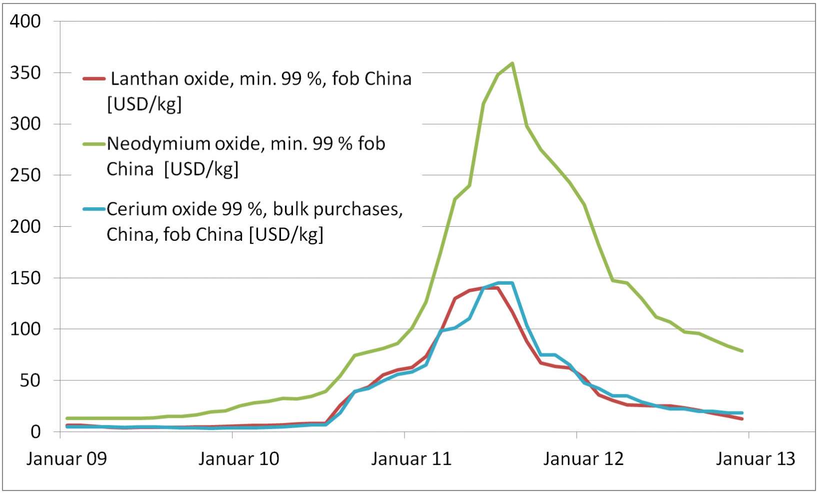
Investments in infrastructure depend strongly on available public transport infrastructure and the availability of electric power from a power grid. Because of the wide spread of capital expenditures published for the erection of infrastructure, no numbers are quoted here for comparison.

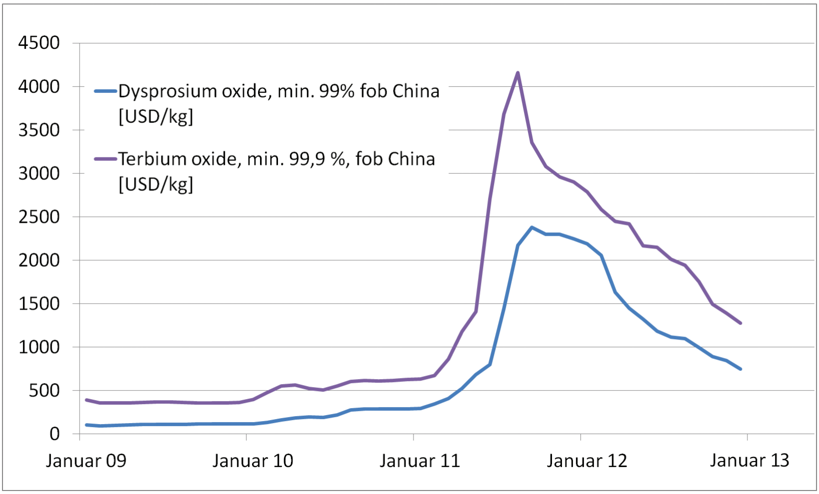
Preparation and operation of waste sites and tailing ponds, mine closure and rehabilitation also require high investments. For a 4,000 t per day mine with a life of mine of 25 years, setting aside 5 - 10 % of total investments for waste management and mine closure appears to be adequate.

Total product costs
For mines in which RE are the main or only product, total production costs for 1 kg of TREO range from 10 to 25 US$/kg, adding up the initial and sustained capital expenditures and operating costs, divided by the total production over the life of mine. Operating costs contribute about 2/3 and capital expenditures contribute 1/3 to the total costs. These figures are only a rough guideline because profits and taxes are not included in much of the published cost information. Carbonatite-hosted REE deposits are at the lower cost scale.

Capital and operating expenditures are strongly dependent on the performance of the processing plant, the recovery, and the consumption of reagents. For the Mongolian RE deposits, these processing tests still have to be carried out before an educated estimate of the viability of the Mongolian RE deposits can be made.

Fig. 2: HREE and LREE prices, January 2009 to December 2012
(Source. BGR in-house database)





RE price development

Because of supply shortages in 2010 and 2011, RE prices increased dramatically and lead to the intensification of RE exploration. However, it was the demand side which calmed the tense market situation by substitution and miniaturization of appliances. Since the middle of 2011, the price trend is downward for all 15 REE. The price trends from 2009 until the end of 2012 are shown in Figure 2.

The prices of the individual RE elements are very different from each other and those ores which contain a high proportion of high-prices REE have a definite economic advantage. The unit price of an RE ore is expressed by a "basket price" which is the theoretical price that could be obtained for one kilogram of fully separated rare-earth oxides, containing rare-earth oxides in the same proportions as found in-situ within the deposit. Apart from RE, many by-products may contribute to the mine revenue. Niobium, zirconium, uranium, tantalum are often by-products or co-products from RE deposits associated with alkaline intrusive complexes, while phosphate, fluorine, and iron may be by-produced from carbonatite-type ore. Phosphate is raw material for the production of fertilizer, and fine-grained iron by-products are used in upgrading coal by washing. There is a market in Mongolia for both of these by-products. The results of systematic sampling of the entire ore bodies, determination of the REE basket price, the technological investigations on the recovery of REE, and the feasibility of by-products or co-products have not been made available, but are important for the assessment of the deposits and should enter any assessment scheme.

5 Global supply and demand situation and resources of RE

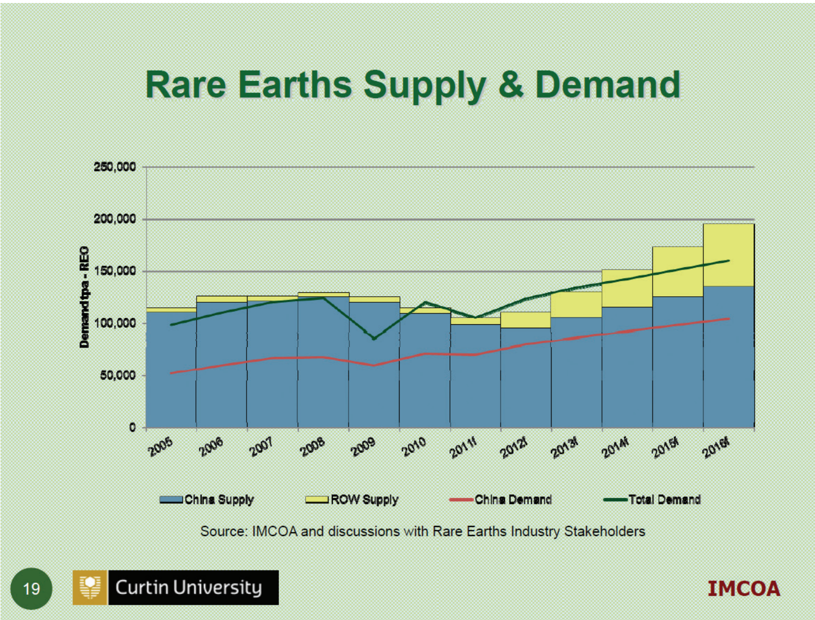
5.1 Supply and demand

The latest estimates of REO production figures cover 2011 and are shown in Table 5. The numbers reflect the production of traded commodities, which may be ore, concentrate, intermediate products (e.g., RE chlorides) or RE oxides. Intermediate products and oxides are expressed as REO equivalents.

Country	product	2009	2010	2011
USA	ore			
	REO equivalent	2,150	1,483	3,516[1)]
India	monazite			
	RE products	16		
Brasilia	monazite	303	249	290
Russia	ore			
	loparite concentrate	6,510	5,339	6,147
	REO equivalent[2)]	1,898	1,495	1,444
China	REO equivalent	129,400	118,900	96,900
Sri Lanka	monazite		86	
Malaysia	monazite	25	732	
Vietnam	monazite[3)]	15,517	20,030	22,330

Table 5: RE production by country, in tonnes. [1)] includes production in Estonia from ore coming from USA; [2)] export; [3)] as far as communicated; empty cells: no production; REO equivalent: various products summed up and calculated as REO. Source: BGR in-house database.

Figure 3: RE supply and demand. Source: Kingsnorth[12]



In the 3rd Quarter of 2012, a Kazakh-Japanese joint venture finished construction of an RE plant which will process tailings from uranium ore processing. The JV plans to export 1,500 tpa of RE-oxides (mainly HREE) to Japan and France. India also announced that it is at the brink of producing REO from monazite ore in marine placer deposits[11].

In 2012, Molycorp announced that it remains on track to begin producing REO at an annual rate of 19,050 metric tonnes of REO in the fourth quarter of 2012 and, if customer demand and end-market conditions warrant, a full planned production rate of 40,000 tonnes of REO per year as early as mid-2013.

In January 2013, LYNAS Corp. announced that it anticipates that commercial rare earth products will be available in the early months of 2013.

It is expected that the number of RE-producing countries will increase in 2016 because several RE exploration projects are targeted to produce a few years from now.

The production of RE shows some noteworthy features which distinguishes it from other mineral raw materials:

a) The largest part of RE are mined as by-products or co-products, about 53 % of the global RE production comes from the Bayan Obo mine alone, were iron is the main product.

b) RE mines possess a characteristic compositional spectrum (REE occur in a "bouquet") and the individual elements of the group cannot be mined selectively.

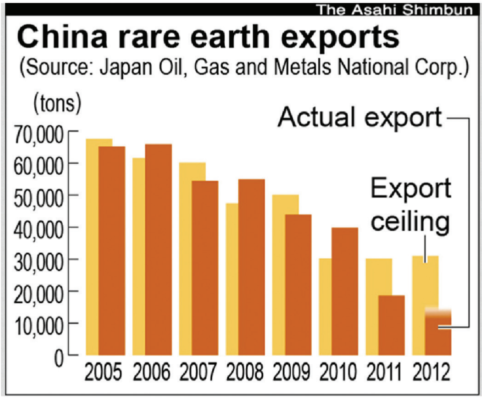
Therefore, it will be difficult for the supply side to match the demand for individual REE.

The RE demand and supply for China and the rest of the world has been estimated by Mr. Kingsnorth and shown in a number of presentations. Fig. 3 is taken from a lecture by Mr. Kingsnorth presented at BGR/DERA in 2012[12]. The graph shows that the supply of RE, without distinguishing between LREE and HREE, will slowly but continuously grow stronger than the demand. According to Mr. Kingsnorth, production of the elements outside China will grow tenfold over five years, from 6,000 tonnes in 2011 to 60,000 tonnes in 2015.

Many researchers point out that the present supply squeeze affecting HREE which are important for the manufacture of permanent magnets will continue in the years to come. The US Department of Energy in its '2011 Critical Materials Strategy'[13] report, said provision of the rare earth elements dysprosium, terbium, europium, neodymium and yttrium are already reaching "critical" levels of short-term supply, meaning supply issues could occur from now through 2025. Kingsnorth also points out that the balance between LREE and HREE will still be an issue; and that prices for europium, dysprosium, and terbium will remain strong. He predicts the demand and supply figures for 2016 shown below:

Neodymium:	demand 25-30,000 t REO,	supply 30-35,000 t REO
Europium:	demand 625-725 t REO,	supply 450-550 t REO
Dysprosium:	demand 1,500-1,800 t REO,	supply 1,300-1,600 t REO
Terbium:	demand 450-550 t REO,	supply 300-400 t REO
Yttrium:	demand 12-14,000 t REO,	supply 9-11,000 t RO

Fig. 4: Chinas export quotas and actual export figures.



These figures support the realistic assumption that a few selected RE prospects which contain a high proportion of the REE shown above have a fair chance of stepping up to the production stage.

RE production is dominated by China, which contributes about 90 % of the global RE supply. Increasingly, semi-finished and finished components of high-tech products containing RE are produced in China. With the aim of securing the raw material supply for its high-tech industry, China imposed export quotas and introduced two pricing systems, one for RE export, and one for RE processed within China. China's Ministry of Commerce set the export ceiling for the first half of 2013 at 15,501 tons of REE[14]. LREE contribute 87 % of the export quota, while MREE and HREE make up the remaining 13 %.

Although the export quotas imposed by China were often blamed for a physical RE supply squeeze, it is noteworthy to say that the export ceilings set by the quotas were very rarely reached (Fig. 4).

5.2 Worldwide reserves and resources situation

Table 6 presents the amount of RE contained in known ore reserves and mineral resources. These numbers are useful to provide an estimate of what is likely to be available for mining in the long term, because resources may be transformed into minable reserves by additional investigations.

Country	Reserves (thousand t)	Resources (thousand t)	Percentage of global reserves	Percentage of global resources
China	18,400.0	66,550.0	64	21
Asia (without Russia)	3,763.5	8,836.0	13	3
Mongolia		1,263.8		
Vietnam		1,285.6		
India	3,733.5	6,099.0	13	2
Kyrgyzstan		43.5		
Kazakhstan	30.0	144.0		
Others		154,000		
Australia	990.0	6,020.8	3	2
Europe (without Russia)		16,656.9		5
Greenland		15,733.5		
others		923.4		
Russia (Europe & Asia)	3,344.9	166,076.7	12	53
Africa	29.4	4,763.0		2
South America	25.4	15,565.3		5
Canada		24,630.4		8
USA	2,070.0	5,397.5	7	2
Total (rounded)	28,623.3	314,496.6	100	100

Table 6: Estimates of global RE reserves and resources expressed as contained TREO. Numbers are rounded. Source: BGR, in-house statistics, June, 2013; percentages are rounded, below 1 % are not indicated.

It is probable that ongoing exploration work will substantially increase the known RE reserves and resources.

6 Valuation of principal REE occurrences in Mongolia

Figure 5: Schematic location map of major Mongolian REE deposits. 1 Khotgor; 2 Mushgai Khudag; 3 Khalzan Burged; 4 Lugiin Gol.

This section gives a short description of the criteria which are helpful to evaluate the REE occurrences in Mongolia. Figure 5 shows the location of the Mongolian RE deposits.

6.1 Peer group table

With the intention of finding out how to place the Mongolian REE deposits in a market entry scenario, a peer table of selected REE exploration projects and the Mongolian REE deposits was compiled (Appendix 1). The projects have been taken from available technical reports, public domain information sources (notably from the Advanced Rare-Earth Projects Index of TMR[15]and information available from Canadian Security Administrators (SEDAR filing system of CSA), Australian Securities Exchange (ASX) and the US Securities and Exchange Commission (EDGAR of US SEC). The cut-off date for data collection was December 2012.

An early stage evaluation of REE deposits has to consider many criteria. These are:

- geological factors (quality and quantity of ore body, morphology and dimension of ore body, distribution of valuable elements within the ore body)

- operational factors (production size, mining methods required to extract the ore, dilution and losses of ore during mining, REE recovery during mining, efficiency of ore mineral concentration and REE extraction)
- economic factors (costs along the value chain from mine to saleable product, future demand/supply situation, product price, first-mover-advantage)
- geographical factors (remoteness, availability of energy, transport, water supply)
- political factors of host country (political stability; ease of doing business in host country; legal and regulatory governance of host country)

These criteria have been compiled, as far as possible, in the peer table (appendix 1).

6.2 Valuation criteria

Important criteria in the evaluation of RE deposits are the quality of the deposit and the prevailing global and national economic conditions which have to be considered when developing a deposit. Because of their importance, these two criteria are described in detail below, while the evaluation table (table 9) treats additional criteria which have to be considered at an early stage of deposit evaluation.

Quality of ore deposits

The most fundamental premise for the development of a mine is that enough ore and grade are present in the ground to guarantee that the life of mine revenues are higher than the total costs, and that the quantity of extracted ore can sustainably feed the downstream processing plant. Apart from a high TREO content, the presence of a large mass of ore is an advantageous criterion, because the high up-front capital expenditures for the construction of the processing plant require a long life of mine, preferably of about 10 years and above. The method of choice to show the resource tonnage, ore grade and contained metal mass is the "grade-tonnage diagram".

The grade-tonnage diagram of the peer group including the Mongolian RE deposits is displayed in Figure 6. The carbonatite-hosted RE and the alkaline intrusive complex-hosted RE projects are shown in different symbols, and the Mongolian deposits belonging to these two groups are marked in the diagram.

To facilitate easy estimation of the contained REE contents of the projects shown in Figure 6, lines of equal REE contents of 10,000 t, 100,000 t, 1,000,000 and 10,000,000 t are drawn.

Readers unused to interpreting diagrams with logarithmic scales should be aware that distances in the diagram are not proportional to differences in grade or tonnage.

Carbonatite-hosted group of RE prospects (table 7 and figure 7)

The peer table contains 21 carbonatite-hosted RE deposits. Because of its huge size, the giant Bayan Obo RE mine located in China would introduce biased statistics when comparing the RE deposits, and for this reason it is excluded from statistical treatment. The resource sized of the 20 carbonatite-hosted RE deposits comparable to the Mushgai Khudag, Khotgor and Lugiin Gol deposits of Mongolia (table 7) range from 0.5 to 466.8 Mt with a mean value of 75.03 Mt.

Ore grade ranges from 0.59 to 7.9 % TREOY with a mean of 2.39 % TREO. The highest ore grade is reported by the mines which are already in production (Bayan Obo, Mount Weld, Mountain Pass).

Mushgai Khudag contains 34 Mt of ore at an average grade of 1.36 %, which relates to 0.46 t of TREO. Khotgor contains 40 Mt at an average grade of 1.22 % REO, corresponding to 0.49 Mt of TREO; and Lugiin Gol possesses 0.5 Mt of ore at a grade of 2.67 % REO, which translates to 0.01 Mt of TREO. Regarding their TREO content, the three Mongolian deposits are much smaller than the group mean (1.55 Mt TREO), with Lugiin Gol being at the bottom of the scale. The TREO contained at Khotgor and Mushgai Khudag are close to the median value (0.48 Mt), showing that about half of the deposits of the peer group lie below and half lie above the TREO contents of Khotgor and Mushgai Khudag.

For 16 of the RE prospects, the cut-off grades are available and a mean value of 1.16 % TREOY is calculated. The mean ore grades of both Mushgai Khudag and Khotgor are close to the mean CoG of the group.

Alkaline intrusive complex group of RE prospects (table 8 and figure 8)

The peer table contains nine RE prospects associated with alkaline complexes, of which the Khalzan Burged deposit in western Mongolia is a member. The mineral resources of the group range from 5.3 to 619 Mt with a statistical mean of 185.28 Mt and a mean ore grade of 0.84 % TREO. The CoG for six projects has been published: the mean grade is 0.64 % TREO. Compared to these values, Khalzan Burged (49 Mt of ore with a mean ore grade of 0.6 %) is a low-tonnage, low-grade deposit with an ore grade comparable to the mean CoG of the peer group. RE deposits hosted in alkaline intrusive complexes often contain additional rare metals as co-products or by-products and further exploration work is necessary to find out whether the tantalum, niobium and zirconium present in Khalzan Burged can be economically recovered.

Economic criteria

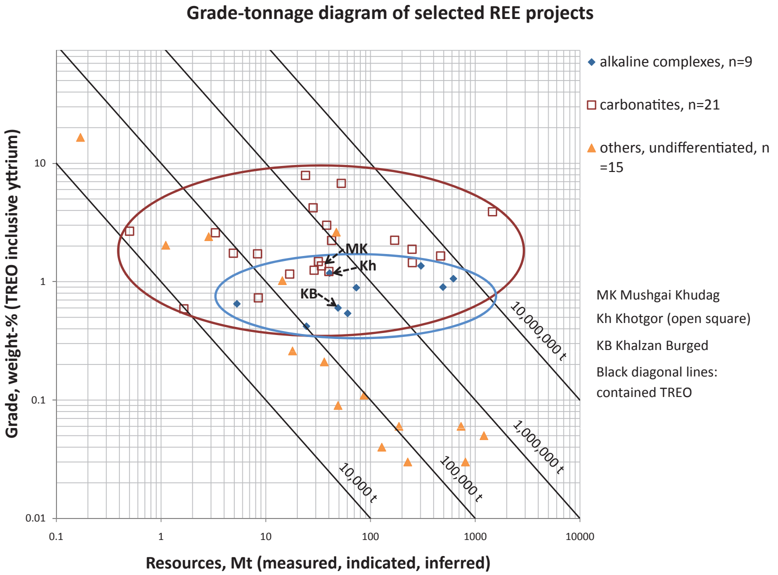
Production costs, early mover advantage, and the basket price are important economic criteria when comparing the Mongolian RE deposits to the members of their peer groups.

The year-round operation of a RE mine and processing facility requires a well-developed transport infrastructure because a large amount of material, fuel and chemicals has to be transported. Among the Mongolian RE deposits, Khalzan Burged is the most likely one which may encounter a transport problem. However, transportation costs for RE projects in East Africa or the northernmost parts of Canada will also be high, and therefore, transportation costs alone will not be a decisive disadvantage of the Mongolian deposits.

The price for diesel fuel contributes markedly to the operating expenditures. The Worldbank published diesel pump prices for the year 2010[16], and from these data one may arrive at the following relative price indices: Mongolia 1, Canada 1.1, Australia 1.2, Tanzania 1.2, Mali 1.3 and the USA 0.8. Mongolian diesel prices are comparable to the prices in Canada, while it has a slight cost advantage to Australia and Mali; however, it is disadvantaged in relation to the USA.

At the moment, Mongolia may have a slight advantage with labor costs, but because of wage inflation, this advantage will be lost soon.

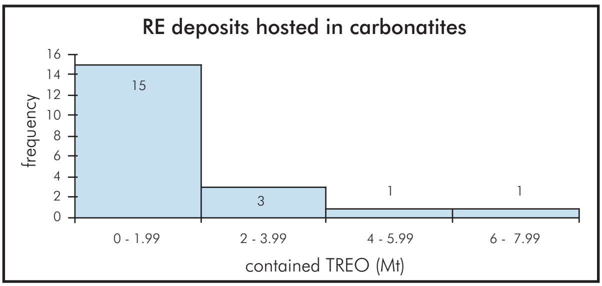
Figure 6: Grade-tonnage diagram of peer group and Mongolian RE deposits. The total number of deposits plotted is 45 (data from peer group table, Appendix 2). Brown line encloses carbonatite-hosted RE deposits; blue line marks RE deposits located in alkaline intrusive complexes.



Deposit	Ore (Mt)	Grade %	TREO (Mt)	CoG %
Araxá	28.29	4.21	1.19	1.25
Ashram	249.1	1.88	4.68	
Bear Lodge	38.13	3.0	1.14	1.5
Clay-Howell	8.48	0.73	0.06	0.6
Cummins Range	4.9	1.74	0.09	1.00
Glenover	28.93	1.25	0.36	1.0
Khotgor	40	1.22	0.49	
Lavergne-Springer	16.9	1.16	0.20	0.9
Lofdal	1.65	0.59	0.01	0.3
Lugiin Gol	0.5	2.67	0.01	
Montviel	250.6	1.45	3.63	1.0
Mount Weld	23.94	7.9	1.89	2.5
Mountain Pass	52.56	6.77	3.56	3.0
Mushgai Khudag	34	1.36	0.46	
Ngualla	170	2.24	3.81	1.0
Niobec	466.8	1.65	7.7	0.5
Sarfartoq	8.34	1.72	0.14	1.0
Songwe	31.75	1.48	0.47	1.0
Wigu Hill	3.3	2.59	0.09	1.0
Zandkopsdrift	42.48	2.23	0.95	1.0
Arithmetic mean	75.03	2.39	1.55	1.16
Min value	0.50	0.59	0.01	0.30
Max value	466.80	7.90	7.70	3,00
Median	30.34	1.73	0.48	1

Table 7: Tonnage, grade, contained TREO and CoG of carbonatite-hosted REE deposits listed in peer table (appendix 1)

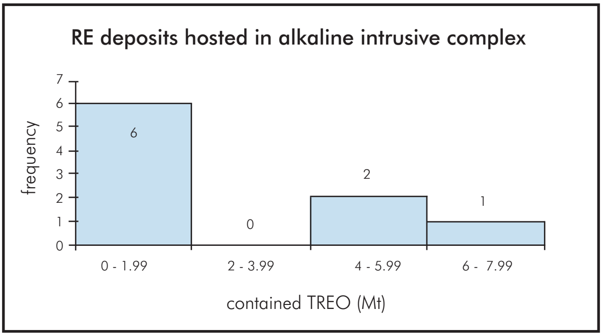
Figure 7: Frequency distribution of REO contained in carbonatite-hosted RE deposits. Khotgor, Mushgai Khudag and Lugiin Gol are in the lowermost group.



Deposit	Ore (Mt)	Grade %	TREO (Mt)	CoG %
Bokan Mountain	5.3	0.7	0.03	
Dubbo Zirconia Project	73.2	0.89	0.65	1.5
Khalzan Burged	49	0.6	0.29	
Kipawa	24.45	0.42	0.1	0.2
Kvanefjeld project	619	1.06	6.56	
Nechalacho upper & basal	303.44	1.36	4.13	
Norra Kärr	60.5	0.54	0.33	0.4
Strange Lake	492	0.9	4.43	0.5
Two Tom	40.64	1.18	0.48	0.6
Arithmetic mean	185.28	0.84	1.89	0.64
Min value	5.30	0.42	0.03	0.20
Max value	619.00	1.36	6.56	1.50
Median	60.50	0.89	0.48	0.50

Table 8: Tonnage, grade, contained TREO and CoG of alkaline intrusive complex type of REE deposits of peer table (appendix 1)

Figure 8: Frequency distribution of REO contained in RE deposits hosted in alkaline intrusive complexes. Khalzan Burged is in the lowermost group, which hosts six of the nine deposits.



7 Conclusion

The available geological, technical and economic data on the Mongolian REE deposits is too scarce and unreliable to apply quantitative analytical methods for their evaluation. Instead, an attempt is made to compile and rate all criteria in an evaluation table (Table 9). The criteria which are applied to evaluate the viability of the Mongolian RE deposits are arranged in five groups as follows: ore deposit quality; economic criteria; environmental criteria; infrastructural criteria; governance criteria.

REE analysts predict that the supply squeeze for the critical REE will come to an end once one or two additional RE mines start production. The time window for new mines to enter the market is only a few years wide. Therefore, any future RE production candidate should have a low-cost high-grade deposit in its portfolio, the prospect should be at an advanced development stage to meet the time window, and the deposit should have the right mixture of REE spectrum. There are many rare earth prospects under investigation which meet these criteria better than the Mongolian rare earth deposits.

Criteria in Table 9 which are specific to individual mines and locations were rated according to the findings of the text body of this report. For the "governance criteria" which deal with general conditions in Mongolia, the FRASER Survey of Mining Companies 2011/2012[17] (for brevity "Fraser Report") was consulted and reference is made to specific questionnaires in said report. The Fraser Report surveyed 93 mining jurisdictions.

Attention should be given to the "governance criteria". Long processing times for the many permits and a cumbersome administrative, legal and political environment may put an end to a prospective REE project.

The ratings in Table 9 indicate that none of the Mongolian RE deposits possesses decisive advantages over their competitors. The Mongolian RE deposits have been on the radar of RE companies for some time, but the country is still a long way from becoming a RE producer. It is expected that the recent exploration efforts in Khalzan Burged, Khotgor and Mushgai Khudag will extend the ore inventory and perhaps provide more information on the costs and technology of the REE processing.

The recommendations of this report plug into the ideas put forward by ELSNER and his colleagues in 2011[1]: they did not recognize a comparative advantage for the Mongolian REE deposits and they proposed that consideration should be given to selling a physical concentrate to a processing facility in China, or a joint processing plant for the carbonatite-hosted REE deposits located in the South Gobi.

Criteria	Description and remarks	Rat-ing
Ore deposit quality:		
Tonnage, grade	Concerning the contained TREO; Khalzan Burged belongs to small deposits, and its mean TREO grade is about the CoG of the group. The presence of tantalum, niobium, zirconium may be advantageous, if recoverable.	-
	Regarding the TREO contents, Mushgai Khudag and Khotgor are at the lower end of the peer group.	-
	Lugiin Gol is too small to be relevant and is not considered any further.	--
Complexity of mineral composition/ intergrowth	Khalzan Burged: complex composition, preliminary tests indicate problems when producing concentrate.	-
	Mushgai Khudag, Khotgor: no preliminary test available	
Presence of high-price REE	The carbonatite-hosted RE deposits provide mainly LREE and contribute little to the supply of the high-priced critical REE.	
	Information on Khalzan Burged is not robust enough to make a statement.	
Economic criteria:		
Capital and operational expenditures (mainly labor cost, fuel costs)	Generally, the Mongolian RE deposits neither have a decisive cost advantage nor disadvantage compared to most members of their respective peer group.	+/-
Costs for nature use	Probably somewhat lower in Mongolia than in Canada, Australia or the US; perhaps comparable to East African host countries	+/-
Procurement of chemicals (reagents, acids, others)	Large volumes have to be imported, therefore currency exchange risks; dependence on delivery from Russia or China;	-
Offtake agreements, financing	Solid financing not in place.	-

table continued

Criteria	Description and remarks	Rat-ing
Environmental criteria:		
Rehabilitation and mine closure costs and procedures	Environmental policy and legislation in Mongolia is in place and rules are fairly transparent; but no experience yet with the application of the new Minerals Law. The Fraser Report ranked Mongolia in place 53 out of 93 in the questionnaire "Uncertainty concerning environmental regulations" and it is only a "mild deterrent to investment". On the whole, neither advantage nor disadvantage for Mongolian deposits.	+/-
Waste management	REE processing is invariably associated with the accumulation of radionucleides in solid waste and effluents. It may be expected that the Ministry for Environment and Green Development will strictly implement the Environmental Law, and make no concessions. The presence of radioactive elements is considered rather a nuisance than an asset.	-
Infrastructural criteria:		
Proximity to public infrastructure	Some projects of the peer group are close to functional and reliable infrastructure, some are in remote areas; therefore, no decisive advantage or disadvantage for the Mongolian deposits.	+/-
Presence of transport infrastructure	As above	+/-
Availability of consulting and construction services	Established consultancy for mine planning, ESIA, drilling programs, and others are available.	+

table continued

Criteria	**Description and remarks**	**Rat-ing**
Governance criteria:		
Technical and skill risk	Shortage of skilled engineers and technicians	-
Administrative, political and business environment	Inefficient public sector institutions, cumbersome administration Mongolia has a history of fraudulent procedures in obtaining exploration and mining licences Professional associations and business counsels predict that the new Minerals Law (still under review) will cause an exodus of investors The regulatory risk for receiving permits for the storage and handling of radioactive waste is considered high because many institutions at various governmental levels are involved The Fraser Report ranked Mongolia in place 60 out of 93 in the questionnaire "Uncertainty concerning administration, interpretation, and enforcement of existing regulations" and most interviewed persons said they "would not pursue investment due to this factor" In the "Policy Potential Index" of the Fraser Report, Mongolia occupies place 77 out of 93	--

Table 9: Evaluation table for Mongolian REE deposits; rating: + advantageous; ++ very advantageous; - disadvantageous; -- very disadvantageous; +/- neither advantageous nor disadvantageous; blank: no information for rating

Appendix 1: Peer comparison table of selected REE projects

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Araxá Brazil	28.29	4.21	Phosphate, REE, niobium	PROD	OP; supergene enrichment; gradational contacts	Carbonatite	LoM 40+ years; Capex 406 million US$ phase 1, plus 214 million US$ for later expansion
Ashram (Main plus MHREO Zone) Canada	249.1	1.88	REE, tantalum, niobium (+ fluorine?); REE in monazite, minor bastnaesite and xenotime; CoG: 1.25 %	EXPL	OP; hard ore, drilling and blasting; tabular ore body; irregular distribution of ore minerals within ore body	Carbonatite, no supergenic enrichment	Thin overburden; Capex 763 million CDN$; simple mineralogy; LoM 25 years; ESIA still pending; located in remote area; electric power from own supply; no radioactivity or hazardous waste problems
Bayan Obo China	1460	3.9	REE, niobium are co-products of iron mining; Resources and CoG determined by iron mining economics	PROD	OP; hard ore; several ore bodies in pit	Carbonatite, hydrothermal replacement	Main supplier of RE for China and global market
Bear Lodge (Bull Hill SW area), USA	38.13	3	REE; main minerals: bastnaesite, monazite; CoG: 1.5 %	EXPL	OP; drilling and blasting; gradational contacts; irregular distribution of RE within ore body	Carbonatite; veins and dikes within alkaline complex	LoM 19 years; excellent infrastructure; Life-of-Mine capex US$404.18 million; Thorium occurs in bastnaesite and separate minerals

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Bokan Mountain (Dotson Shear and I&L Shear Zone) USA	5.3	0.65	REE, niobium, zirconium, uranium, thorium; high HREE (40 % HREO of TREO)	EXPL	UG; wide vein zone, exposed at surface, with many steeply dipping veins	Peralkaline intrusive complex	Pre-existing contamination of site by uranium mining is confirmed and clean-up responsibility is to be determined; remote location; no electrical infrastructure
Buckton Canada	226.9	0.03	Polymetallic deposits; specialty metals; REE and scandium	EXPL	OP; blasting and drilling	Sedimentary; black shale close to surface	Remote area; no access to power grid; metal extraction by heap-leaching or bioleaching
Canakli I Turkey	49	0.09	REE, zirconium, titanium; ore minerals: allanite, chevkinite and sphene	EXPL	OP; unconsolidated ore similar to heavy mineral sands	Pyroclastic tuff; fine grained; ore minerals are already partially to completely liberated	Problematic: storage of contaminated waste; good public infrastructure; energy and water available
Charley Creek Australia	805.3	0.03	REE, zirconium; RE are contained almost exclusively in monazite and xenotime; about 17 % of REO are HREO; cut-off between mineable and non-mineable alluvium: US$4.30/tonne	EXPL	OP; superficial, soft ore	Large volume placer	Low-cost high-volume mine; proven extraction method

table continued

Appendix 1: Peer comparison table of selected REE projects (continued)

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Clay-Howell Canada	8.48	0.73	REE, iron, perhaps niobium; CoG: 0.6 %	EXPL	no information as to mining type	Carbonatite; veins and dikes in alkaline complex	Mineralogy is complex, but primarily consists of Ce-La-Ca silicates and monazite;
Cummins Range Australia	4.9	1.74	REE (+ uranium?); CoG: 1.0 %	EXPL	OP, drilling and blasting; gradational contacts; irregular distribution of REE in pit resource model	Regolite on top of primary carbonatite diatreme	Carbonatite-iron oxide-copper-gold family of mineral deposits; low strip ratio; soft ore; uranium and phosphate may pay; suitable location
Dubbo Zirconia Project Australia	73.2	0.89	Co-products: zirconium, REE, niobium and others; CoG: 1.5 % (ZrO_2 + Nb_2O_3 + Y_2O_3 + REO)	EXPL	OP; tabular ore body, sharp contacts; fairly regular distribution of value minerals within ore body	Sub-volcanic trachyte horizontal intrusive body; ore very fine grained (most grains less than 20μm) and of extremely rare compositions	LoM 20 + years (up to 200 y) Major world resource - zirconium, hafnium, niobium, tantalum, yttrium & rare earth elements; contains 100ppm uranium and 350ppm thorium, classified as weakly radioactive; final government approvals could be other major hurdle

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Eco Ridge Canada	86.6	0.11	REE, uranium as co-products; REE in monazite ore	EXPL	UG; hard ore; sharp contacts	Paleoplacer	Infrastructure, water, energy available; LoM 11 y; initial capex 563 million CDN$
Foxtrot Canada	14.40	1.02	REE-zirconium-yttrium-niobium mineralization; ore minerals: allanite, zircon, chevkinite, and fergusonite; CoG: 150 ppm Dy_2O_3	EXPL	OP; sharp contacts, tabular ore body; well-defined pay zones within ore body	Felsic volcanics (not peralkaline)	LoM 10 y; Capex 494 million CDN$; main minerals: fergusonite, allanite and zircon
Glenover South Africa	28.93	1.25	REE; by-products are phosphate, niobium; REE in monazite, synchysite and bastnaesite; CoG: 1.0 %	EXPL	OP; low stripping ratio; irregular distribution of pay zones in pit resource model	Calcrete and saprolite over carbonatite and pyroxenite body; stockpiled ore from former phosphate mining	Active phosphate mine from 1963 until 1984; old pit approximately 200 m wide and 100 m deep; presence of uranium and thorium require special permit; metallurgical tests are under way; tarred road nearby, access to electricity and other mining related infrastructure; nearby streams are seasonal
Grande-Vallée Canada	1209.64	0.05	Main commodity: aluminium; REE are by-products	EXPL	OP; superficial, soft ore	Residual	No toxic waste; low waste:ore ratio (0.15); LoM 25 years; Capex (mine and plant): 500 million CDN$ railway and power grid 30 km away

table continued

Appendix 1: Peer comparison table of selected REE projects (continued)

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Hastings Australia	36.2	0.21	REE, zirconium, niobium, tantalum; HREO make up 86 % of TREO	EXPL	OP; tabular ore body with sharp contacts	Hosted by a fine-grained, tuffaceous rhyolitic volcaniclastic unit	LoM 25 years; Capex 500 m A$; high waste:ore ratio (11:1)
Hoidas Lake Canada	2.85	2.4	REE-only; main minerals: apatite, allanite; minor minerals chevkinite, monazite and rare earth element carbonates; CoG: 1.5 %	EXPL	UG; tabular ore bodies (veins)	Structure related veins, pegmatites without direct relation to alkaline, peralkaline or carbonatite magmatic rocks	Remote location; access by road in summer time; no access to power grid; no economic data available
Khalzan Burged Mongolia	49	0.6	REE, zirconium, niobium, tantalum	EXPL	OP; superficial, hard ore; massy orebody with gradational contacts and irregular distribution of grade within body	Alkaline intrusive complex	High content of radioactive elements will produce hazardous waste; low-grade ore; project not connected to power grid; exploration ongoing

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Khotgor Mongolia	40	1.22	REE (mainly LREE); main minerals: bastnaesite, apatite, parasite?, synchysite?	EXPL	OP; superficial, hard ore, several irregularly shaped ore bodies	Carbonatite	Most recent exploration campaign: 2005-2009; remote area, far from power grid; no access to surface water
Kipawa Canada	24.45	0.42	Coproducts: REE, zirconium; main concentrate minerals are eudialyte, mosandrite and britholite; high HREO contents; CoG: 0.2 %	EXPL	OP; drilling and blasting; gently dipping tabular ore body	Alkaline complex; uranium and thorium are contaminants in the main REE-Y-Zr mineralization; no sulfide minerals, therefore no acid drainage problem	Capex: $315.8 million CND $ for mine, hydromet, infrastructure; straightforward mineralogy, ideal deposit geometry, simple processing flow-sheet, most infrastructure in place; LoM 13 years; metallurgical tests underway; tailings probably not classified as „radioactive"; rudimentary transport infrastructure present; not connected to electricity network; surface water (lake) 2 km away waste:ore ratio is 1.53:1
Kutessay II Kyrgystan	18.01	0.26	Basemetals and REE	CON	OP; hard ore, irregularly shaped ore body	Magmatic, unrelated to alkaline magmatism	Infrastructure in place

table continued

Appendix 1: Peer comparison table of selected REE projects (continued)

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Kvanefjeld project (exclusive Sorensen and Zone 3) Greenland	619	1.06	co-products: HREE, uranium, zinc; CoG: 150 ppm U_3O_8	EXPL	OP; hard ore	Layered peralkaline complex	Low waste/ore ratio; high proportion of HREE and Y; Capex of open cut mine, mineral concentrator and refining plant are US$ 1.297 billion (SEP2012 Quarterly Report); LoM: 33 years (up to 50 y)
La Paz USA	128.2	0.04 TREE	REE; main REE-carrier is allanite; CoG: 0.03 % TREE (excluding Y, calculated as ions)	EXPL	No information as to mining method; superficial, hard ore, gradational contacts	Unusual: mineralized detachment fault	Large volume, uncomplicated mineralogy, lack of uranium and thorium, favorable preliminary metallurgical work, and location; 16 % of REO are HREE uranium and thorium levels less than 10 ppm
Lavergne-Springer Canada	16.9	1.16	REE; REE mineral is synchysite; CoG 0.9 %	EXPL	OP	Carbonatite	Simple mineralogy; low radioactivity; good infrastructure; no economic evaluation yet
Lofdal Namibia	1.65	0.59	REE; dominance of xenotime in mineralized samples; CoG: 0.3 %	EXPL	OP: superficial, hard ore	Carbonatite	Proposed budget of CDN$ 2.8 million for exploration, drilling, metallurgical tests, PEA; high HREO contents

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Lugiin Gol Mongolia	0.5	2.67	REE (LREE); main minerals: synchysite, parasite, monazite; no cut-off grade available	EXPL	OP; superficial, hard ore	Carbonatite	Deposit comprises many carbonatite veins; remote location most recent exploration campaign: 2005-2009
Milo Australia	187	0.06	Co-products: copper concentrate, REE, yttrium, phosphate, uranium	EXPL	OP	Iron oxide REE	No economic data available; separation flowsheet in preparation
Montviel Canada	250.6	1.45	REE, Nb; CoG: 1.0 %	EXPL	open pit	Carbonatite	Good access and good public infrastructure
Mount Weld (Central Lanthanide and Duncon Deposits) Australia	23.94	7.9	REE; REE mostly in monazite; CoG: 2.5 %	PROD	OP, supergene enrichment over primary ore; drilling and power-shovel	Residual over carbonatite	LOM > 20 years; low thorium contents; low fluorine contents; waste:ore ratio is 4.6
Mountain Pass USA	52.56	6.77	REE; primary REE mineral is bastnaesite; CoG: 3.0 % REO (La_2O_3, CeO_2, Pr_6O_{11}, Nd_2O_3, Sm_2O_3)	PROD	OP; tabular ore body with intermediate inclination; variable grade distribution within mineralized zone	Carbonatite body associated with alkaline intrusion	Mine and concentration plant in operation; waste:ore ratio is 12.3 LoM: 22 years

table continued

Appendix 1: Peer comparison table of selected REE projects (continued)

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Mushgai Khudag Mongolia	34	1.36	REE (predominantly LREE); main minerals: bastnaesite, apatite, perrierite, parasite, synchysite; recent core drilling in 2012 added about 3 Mt of ore	EXPL	OP ?	Carbonatite	Remote location, not connected to power grid, no surface water available; elevated contents of radioactive elements
Nechalacho (upper & basal zones) Canada	303.44	1.36	co-products REE, niobium, zirconium, tantalum; CoG: $ 320/tonne Net Metal Return	EXPL	UG; hard ore, disseminated and stockwork	Peralkaline intrusion	Capex CDN$ 902 million; LoM 23 y; high HREE contents
Ngualla Tanzania	170	2.24	REE; main REE mineral is bastnaesite; CoG: 1 % (applying a CoG of 3%, the reserves are 40 Mt)	EXPL	OP; variable grade distribution	Carbonatite pipe (similar to Mount Weld and Zandkopsdrift) and colluvial gravel	Low uranium and thorium contents; low overburden:ore ratio LoM 25 y; total construction capex 400 million US$; infrastructure and energy supply has to be established
Niobec Canada	466.8	1.65	REE; REE in several fluorocarbonates and monazite; CoG: 0.5 % TREO (without yttrium oxide)	EXPL	UG, near-vertical attitude of ore body; access by drift from nearby niobium mine	Carbonatite	Good infrastructure, operating niobium mine nearby; mining friendly jurisdiction; carbonatite complex covered by competent limestone

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Nolans Bore Australia	47.16	2.62	REE, phosphate, uranium	EXPL	OP; steeply dipping veins	Structure related veins	Mining friendly jurisdiction
Norra Kärr Sweden	60.5	0.54	REE, zirconium, niobium; CoG: 0.4 %	EXPL	OP; hard ore, sharp contacts	Peralkaline intrusion	Norra Kärr has been declared an area of national interest to protect it from other land uses; LoM 40 years; total capex 229 million US$; low levels of uranium and Thorium
Round Top USA	732	0.06	REE, beryllium, uranium; high HREO contents (mainly yttrium); most common rare earth minerals are cerfluorite, yttrofluorite, and yttrocerite; CoG: 428 ppm yttrium (ionic)	EXPL	OP; hard ore; tabular ore body, shallow dip; constant grade distribution within pit model	Near-surface rhyolite/ microgranite intrusion	Good public infrastructure and access; little overburden; LoM 26 years; total capex estimation 2 billion US$; low-cost production ($ 48/kg TREO sold)
Sarfartoq Greenland	8.34	1.72	REE (perhaps niobium, tantalum); REE minerals: monazite, bastnaesite, synchysite; CoG: 1 %	EXPL	UG; hard ore; tubular body with intermediate dip; variable grade distribution	Carbonatite, sub-circular complex	Mining-friendly jurisdiction; metallurgical tests ongoing; remote area, deep water access within 20 km

table continued

Appendix 1: Peer comparison table of selected REE projects (continued)

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Songwe Malawi	31.75	1.48	REE; REE primarily in synchysite (with minor parisite) and apatite, with relatively minor florencite, trace amounts of monazite; CoG: 1 %	EXPL	OP; hard ore; irregularly shaped, subvertical ore body; variable grade distribution	Carbonatite vent, spatially associated with alkaline province	Located in undeveloped area; surface water source (lake) 5 km away; low waste:ore ratio; about 7 % of TREE are HREE; metallurgical scoping work is ongoing no economic information yet
Steenkampskraal South Africa	0.13 (in situ, apart from heaps)	18.75 TREO	REE and thorium; REE and thorium in monazite; CoG (in situ ore): 3 %, without yttrium (May 18, 2012);	CON	UG; steeply dipping veins with sharp contacts; 0.2 to 4.5 m wide	Vein type (magmatic? separation of immiscible magmatic liquid) ore minerals: monazite	Capex 30 million US$ (estimate 2009, company presentation, probably outdated); high thorium content;
Strange Lake (combined granite and enriched zones) Canada	492	0.9	Co-products: REE, zirconium, niobium; high proportion of HREE and yttrium; CoG: 0.5 %	EXPL	OP, hard rock; irregularly shaped ore body; pegmatite-hosted, variable grade distribution	Peralkaline granite complex	Remote area with no infrastructure in place; total project capital costs estimation CAD$563 million; LoM 25 years, minimum mining right granted
Two Tom Canada	40.64	1.18	Co-products: REE, niobium, beryllium; REE in monazite and cerium-calcium silicate; CoG: 0.6 %	EXPL	OP, hard rock; steeply dipping tabular ore body; variable grade distribution	Peralkaline complex	Remote location, no infrastructure; high thorium contents

Project	Mineral resources & ore reserves, (Mt)	TREO (wt%) incl. Y	Value elements; CoG (cut-off grade), TREOY	EXPL: exploration CON: construction PROD: production	Ore deposit morphology and mining method (OP: open pit UG: underground)	Deposit type	Remarks (infrastructure; environmental liabilities; economic metrics) LoM: life of Mine
Wigu Hill Tanzania	3.3	2.59	LREE; main minerals : bastnaesite, monazite, synchysite; almost exclusively LREE; CoG: 1.0% LREO5 (sum La_2O_3, CeO_2, Pr_6O_{11}, Nd_2O_3, Sm_2O_3)	EXPL	OP; irregular internal distribution of pay shoots	Carbonatite	Accessible by all-weather road; railway siding 12 km away; host country with an established mining industry; low uranium and thorium, but activity and exposure levels will have to be dealt with; ongoing exploration could enlarge mineral reserves
Xiluvo Mozambique	1.11	2.03	REE, phosphate	EXPL	OP; superficial, soft ore	Colluvial	Transport infrastructure (road and rail) nearby
Zandkopsdrift South Africa	42.48	2.23	REE in monazite; CoG: 1.0 %	EXPL	OP, superficial soft ore; irregularly shaped ore body; variable grade distribution	Carbonatite pipe with supergene enrichment	Complex metallurgy; contaminated waste management; desalination of water from own supply; electric power from own supply; estimated capex of USD 910 million; LoM 20 years

Explanation: by-products/co-products: see table 3; LoM: Life of Mine
The tonnage and grade of ore deposits depends on the chosen cut-off grade. Cut-off grades are subject to changes because they depend on recovery, and market situation and cost structures of operation; therefore, tonnage and grade of REE prospects may vary according to ongoing exploration work, extraction tests and changing market conditions.
In the case of REE produced as co-products or by-product, tonnage and ore grade values are calculated on the basis of the main product or, sometimes as a combination of all saleable products. If a description of how the cut-off grade, ore grade and tonnage were calculated were to be provided for all projects, the peer table would become too complicated. For this reason, the cut-off grade is only shown for "REE-only" projects and in cases when common RE minerals are the most important value minerals. Note that some sources record the cut-off grade in TREO, TREE, or TREOY

Appendix 2 : Mongolian RE Deposit Passports

The information on the deposits has been compiled from data submitted to MRAM, and information obtained in the public sector or from field visits and interviews.

Company proprietary data has not been included.

Name of property: Mushgai Khudag (also: Mushgai hudag)
Value elements or minerals: Rare earth elements
Location: Administratively the deposit belongs to Mandal-ovoo soum of South Gobi Aimag; Coordinates of Khuren Khad (Apatite hill), which is a prominent hill approximately in the centre of the license area: 44° 23′ 04′′ N; 104° 00′ 40′′.
Access, infrastructure: Access by all-season dirt road; no adequate transport infrastructure in place; no access to surface water; high voltage power line approximately 260 km to NW. Olon Ovoot open pit gold mine is located approximately 17 km to the NE and is connected by dirt road. Nearest settlements are Mandal Ovoo village (32 km) and Bulgan village (55 km). Nearest small airport at Dalanzadgad, about 100 km to the South.
Exploration history: The Mushgai Khudag rare earths deposit was discovered in 1975, prospected in 1983-1984 by the Mongolian government, and explored in more detail between 1989 and 1994 by private companies. The most recent exploration campaign took place between 2007 and 2012 by the Mongol Gazar Company. Rare-metal-hosting alkaline magmatic rocks first determined in early 1970′s by Soviet-Mongolian scientific Academies expeditions. Scientific research continued until mid 1980s.

Development status:

Exploration stage; laboratory tests on mineral separation have been carried out; no pilot plant tests on ore dressing or REO separation have been conducted.

Deposit type:

Carbonatite-hosted deposit associated with alkaline syenite-trachite volcanic-plutonic complex.

Mode of ore occurrence:

Carbonatite and alkaline complex forming a ring structure of about 27 km diameter.

Primary carbonatite is overlain by regolith.

Petrography of host rocks:

Main plutonic host rocks are nephelinic syenites, granosyenite and shonkinite porphyries.

Trachite and latite are the dominant volcanic rock type.

Ore types and ore mineralogy:

Mushgai Khudag presently hosts six ore zones (Tumurtei ore zone, Khuren Khad ore zone, Main ore zone, High Grade ore zone, Monazite ore zone, Jonshit ore zone) with tens of different ore bodies, which may be steeply dipping tabular or lenticular, breccias, stockworks and veins or subhorizontal volcanic sheets.

Four styles of mineralization have been reported: carbonate cemented mineralized breccia; mineralized carbonatite (mainly "apatite-bastnaesite ore"); magnetite-apatite ore, and apatite ore (mainly "phosphatic ore").

Regarding the composition, apatite-bastnaesite carbonatite ores and apatite ores are the most important ones, and each of them has been subdivided into several specific types.

Main REE minerals are: bastnaesite, apatite, perrierite, parisite, synchysite; minor ore minerals are iron minerals, phosphate minerals, and monazite.

Resource situation:

The reserves and resources of the deposit as per June 2012 are about 232,000 tonnes of REO, plus the reserves and resources for the newly found Monazite and Jonshit ore zones (Total: 82,490 t RE2O3). The total amount of reserves and resources is about 314,000 tonnes of RE2O3.

In 2011, these resource volumes were registered with the Professional Mineral Resources Committee of Mongolia: 16,430,639 t of ore, grading 1.41 % REO (categories B+C), that is 231,808 t net REO; prognosed resources (P1 and P2) are not included in the deposit passport.

ELSNER et al. (2011)[1] report 23,637,259 t of ore of category C2, containing 246,940 t of REO.

Personal communication (anonymous, July, 2012) revealed a total of about 314,000 t of net REO, including the newly discovered ore bodies of the Monazite and Jonshit ore zones.

The composition spectrum of individual REO has not been determined.

Resource estimate uses the Mongolian classification system (similar to the Russian system, see Chapter 3.2 of text body of report) which is not compliant to the CIM or JORC system.

Ore dressing:

No pilot plant test have been carried out.

Processing would be difficult because of the presence of several different ore types and REE minerals; elevated radioactivity (U, Th).

Environmental considerations:

The low grade will give rise to large waste dumps and tailing ponds.

Radioactivity associated with the ore may require precautions in the production steps carried out in confined spaces and deposition of waste stream products. Permits for hazardous waste may be required.

Relevant literature, data sources:

4385 hydrogeological study; 4516 geophysical study; 4680 1:50 000 geological mapping; 4714 prospecting-evaluation; 4795 1:10 000 prospecting; 3875 –pre-evaluation; 4173 scientific work; 6319 REMET exploration report; 6710 Mushgai Khudag exploration report; ELSNER et al (2011)[1].

The latest data registered at MRAM has not been made available.

Passport prepared by:

Tamiraa A. and R. Muff, January 2013

Name of property: Khotgor (also: Hotgor)
Value elements or minerals: Rare earth elements
Location: Umnogovi Aimag, Southern Gobi Desert; Southern Gobi; the deposit lies 68 km north-east of Dalanzadgad town in Umnugovi Aimag; Coordinates of point within license: 44° 07′ 47′′ N; 104° 40′ 19′′ E
Access, infrastructure: No public infrastructure present; access by gravel road; no access to electric power grid; no surface water available. Nearest small airport at Dalanzadgad.
Exploration history: The Khotgor rare earths deposit was discovered in 1979-1982 during a Soviet-Mongolia joint mapping project; Between 2005 and 2009, QGX LLC., a Canadian listed company, carried out detailed exploration work including core drilling; In the summer of 2012, further core drilling was carried out by QGX LLC.
Development status: Exploration stage. Laboratory tests on mineral separation have been carried out; but no pilot plant tests on ore dressing or REO separation have been conducted yet.
Deposit type: Carbonatite, with metasomatic and hydrothermal activity.

Mode of ore occurrence:

Tubular, steeply dipping ore bodies (breccia pipe, veins).

The width of individual ore bodies ranges from 1-30 meters, and they extend lengthwise from 10-150 metres along strike.

Petrography of host rocks:

carbonatitic breccias and veins

Ore types and ore mineralogy:

Complex ore mineralogy; two different types of apatite ore are recognized: magnetite apatite ore and fluorite-celestine-magnetite-apatite ore;

Identified REE minerals: bastnaesite, apatite, parisite?, synchysite?

Resource situation

39,751,090 Mt @ 1.22 % REO, (categories B+C), containing REO 486,720 Mt; prognosed resources (P1 and P2) are not included in the deposit passport.

Resource estimate uses the Mongolian classification system (similar to the Russian system, see Chapter 3.2 of text body of report) which is not compliant to the CIM or JORC system.

Ore dressing:

100 kg sample has been submitted for testing to Nagrom LLC laboratory in Hong-Kong; results are not available yet.

Environmental considerations:

The low grade will give rise to large waste dumps and tailing ponds.

No reliable information on presence of radioactive minerals.

Relevant literature, data sources:

Report 3676; 1:200 000 geological mapping; 6101 QGX LLC exploration report; 6403 feasibility study; ELSNER et al (2011)[1].

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Name of property:
Khalzan Burged (also: Khalzan Buregtei)
Value elements or minerals:
Rare metals and rare earths
Location:
Khovd Aimag, Myangad Soum, Western Mongolia; 45 km on paved road NE of Khovd town. Coordinates of summit within property: 48° 24′ 23.8′′ N, 91° 56′ 56.7′′ E, elevation 1962 metres. The license area covers 0.81 km^2, a similar satellite body owned by another company covers 0.19 km^2 and lies immediately to the north-west.
Access, infrastructure:
The project can be reached by direct domestic flights from Ulaanbaatar to Khovd, then 15 km by track. 110 kV-power grid a few km away (WES –Russian supplier). Surface water available, Khovd river flows 15 km west of the area.
Exploration history:
1983 – Discovered by Russian-Mongolian Academic expeditions. 1989 – Prospecting by Soviet geologists. 1990 – Trenching, drilling, sampling resulted in preliminary assessment of potential resources by Soviet geologists. 2011 – Prospectivity report and recommendation on further exploration by Micromine. First half of 2012: extended core drilling program by Mongolian National Rare Earth Corporation LLC (MNREC), under supervision of Micromine; results are not available.
Development status:
Exploration

Deposit type:

Rare metal and RE deposit associated with alkaline igenous complex. Exploration history started, when the complex was explored for uranium.

Mode of ore occurrence:

The area is characterized by extensive but low-grade mineralization of rare earths and rare metals in the central part of the mountain range. Within this low-grade mineralization, high-grade ore occurs as gently dipping dikes, as stockworks in K-spar granite and dissemination within alkalic granites and syenites.

Petrography of host rocks:

Mineralisation is related to peralkaline granitic and alkaline syenite bodies.

Ore types and ore mineralogy:

Metasomatic impregnation mineralization of zircon, pyrochlore etc.

Light and heavy REE, Nb, Ta, Zr, Be, and Y

Major ore minerals are: pyrochlore, columbite, elpidite-armstrongite, bastnaesite, zircon, amorphous REE minerals, zircon, zirconium silicates and hydro-silicates.

Pyrochlore and columbite carry tantalum and niobium. The REE occur in many minerals, mainly in bastnaesite, monazite, synchysite, xenotime, and perhaps in fluorite and apatite.

Resource situation:

The Russian geologists have estimated an inferred resource of 160 million tonnes of ore, to a depth of 250 m. They reported average grade and probable metal oxide contents of:

Ta_2O_5: 17.8 thousand tonnes, with an average grade of0.011%
Nb_2O_5: 335.3 thousand tonnes, with an average grade of 0.2%
ZrO_2: 2,402.8 thousand tonnes, with an average grade of 1.46%
Y_2O_3: 183.5 thousand tonnes, with an average grade of 0.112%
RE_2O_3: 489.9 thousand tonnes, with an average grade of 0.3%

In a study specialized on REE, ELSNER et al.[1] estimated a TREO content of 300,000 tonnes, taking an average grade of 0.60 %.

Ore dressing:

Technological tests (prior to 1990) in the Federal Research Institute of Mineral Raw Materials (VIMS, Moscow) indicate that satisfactory recovery of tantalum, niobium, zirconium and yttrium is possible by magnetic separation and flotation.

Environmental considerations:

The presence of high levels of thorium and uranium will lead to the accumulation of solid hazardous waste, and possibly to hazardous effluents.

The presence of high concentrations of sulphide minerals which could cause acid mine drainage has not been reported.

Relevant literature, data sources:

Report 4505 geological mapping at scale 1:50 000.

Passport prepared by:

Tamiraa A. and R. Muff, January 2013

Endnotes and references

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