Heraeus Materials Valley e.V.

Seltene Erden und deren Mineralien

Lagerstätten, Gewinnung, Aufbereitung, Märkte und zukünftige Verfügbarkeit

Dr. Reiner Haus, Dorfner ANZAPLAN GmbH, D-92242 Hirschau, Germany

www.anzaplan.com

Hanau, 20. Januar, 2010

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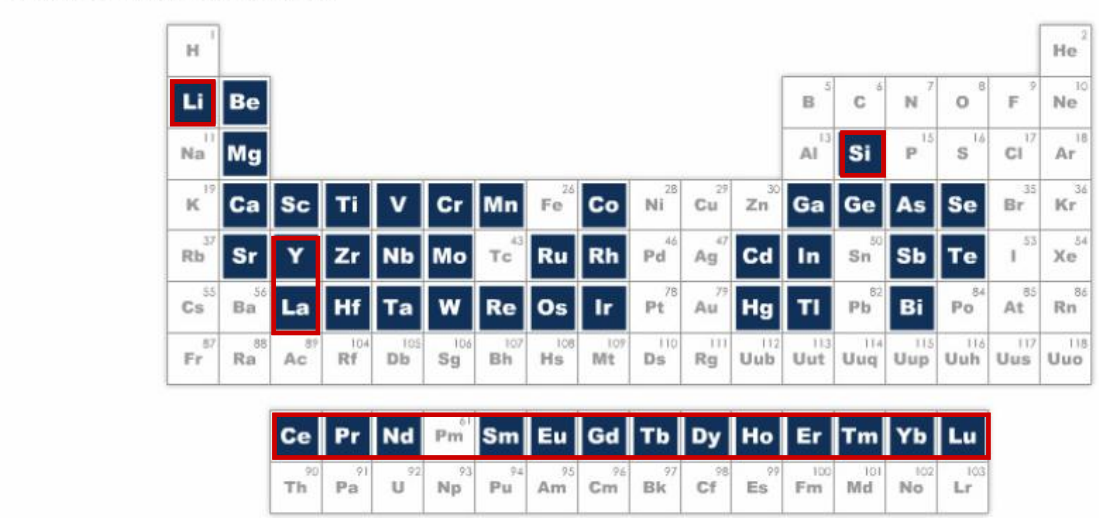
About ANZAPLAN

The Service Company in Strategic Minerals

ANZAPLAN - a full service specialist in high-value industrial and strategic minerals based on long term experience.



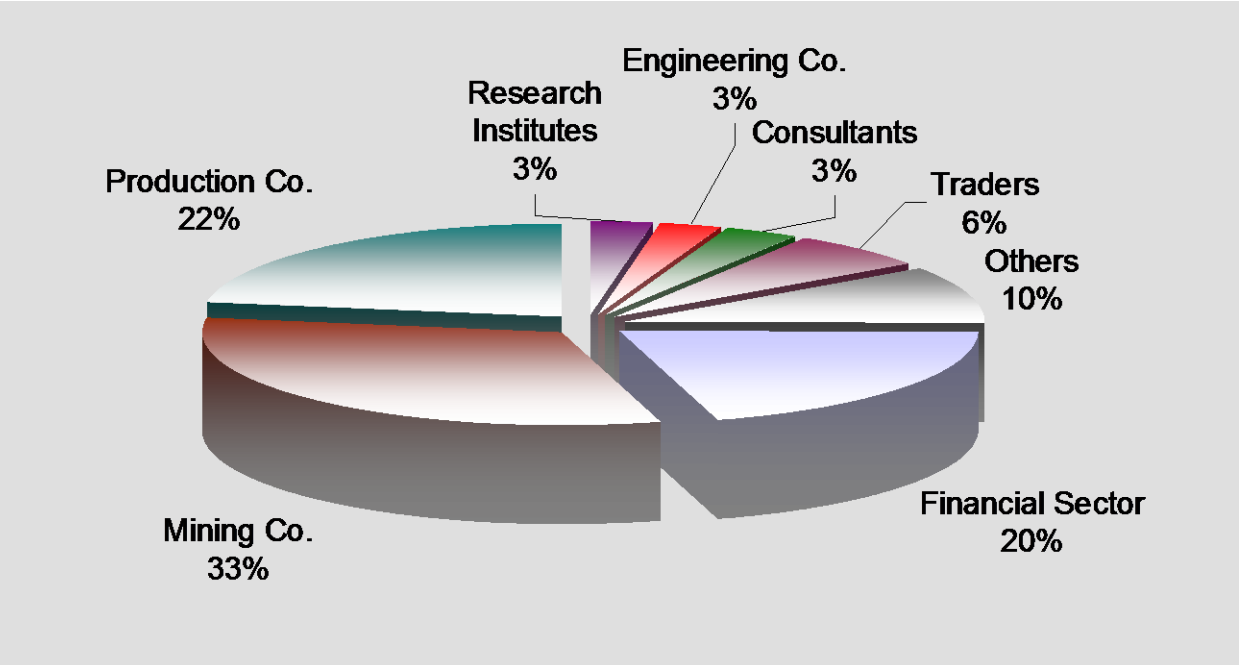
REE Project Valuation by ANZAPLAN

Anzaplan one stop shopping

- Exploration and sampling program (Resources)
- Basic analysis, process design and technology (Reserves)
- Market Potential Analysis
- Sample Production and application tests
- Basic engineering and quality control
- Project Valuation

Who is interested in Strategic Minerals ?

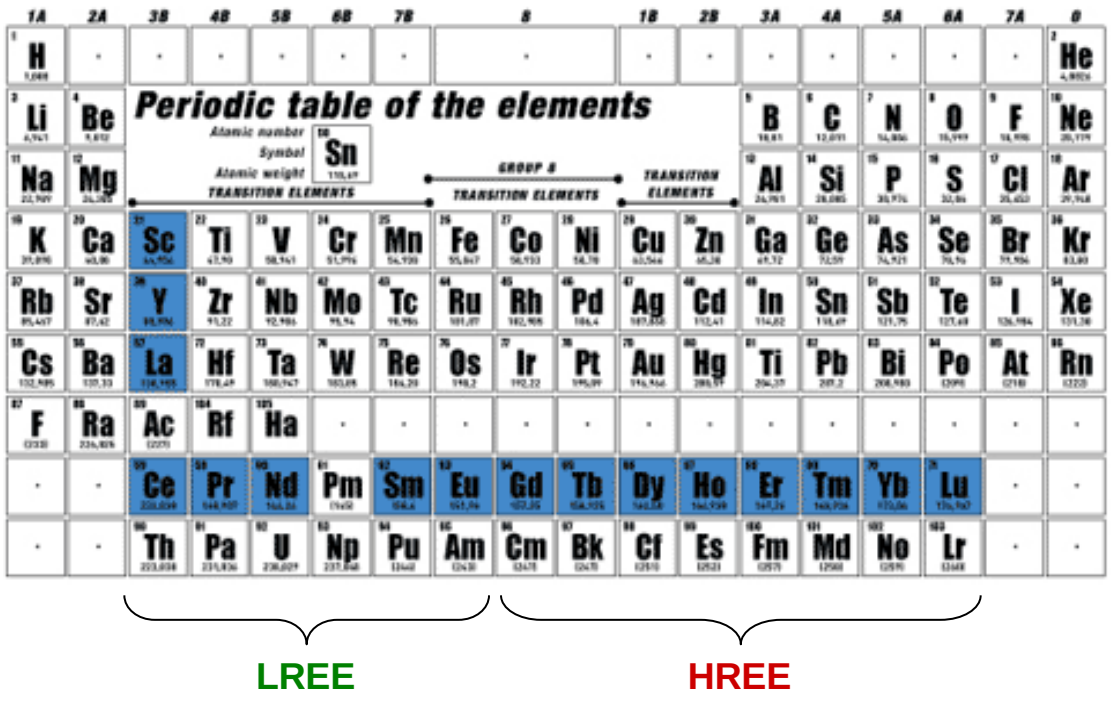
Share of customer contacts and orders 2000-2010



Rare Earths Elements

The Periodic Table

- Rare Earths are a continuous series of 15 metallic elements known as the Lanthanides plus Yttrium.
- The light fraction (LREE), from Lanthanum to Europium and the "Heavies" from Gadolinium to Lutetium accompanied by Yttrium and Scandium.
- Efficient separation processes were not developed until the 20th century because of REEs' chemical similarity.



Rare Earths: A strategic group of elements

The following abbreviations are typically used:

- REE = rare earth elements
- REM = rare earth metals
- REO = rare earth oxides
- LREE = light rare earth elements (La-Eu) ; "Ceriterden"
- HREE = heavy rare earth elements (Y, Gd-Lu) "Yttererden"

Rare Earths: Mineralogy

Important REE-bearing Minerals

Well-known minerals that contain REE include bastnaesite, monazite, xenotime, loparite, eudialyte, steenstrupin, euxenite, florencite, allanit, ancylite, parisite, cheralite, britholite, apatite, cerianite and many more.

Over the years,

- Phosphates, such as Monazite [$(Ce,La,Nd,Th)PO_4$],
- (Fluor-)Carbonates such as Bastnaesite [$LnFCO_3$] and
- specific oxides such as Loparite [$(Ln,Na,Ca)_2(Ti,Nb)_2O_6$]

have been the principal minerals of economic interest for Cerium and the **LREE** …

Monazite crystal, J. Peter, Hannover

Rare Earths: Mineralogy

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have been the principal minerals of economic interest for Cerium and the **LREE** …

while the lateritic ion-adsorption clays are the source where most of the **HREE** are coming from.

REUTERS, A rare earth mine in China.

Rare Earths: Mineralogy

Typical Chemical Composition and REO-Distribution in Monazite (Ce, La, Nd, Th) PO_4

Chemical composition	
SiO_2	1,00 %
Fe_3O_4	0,32 %
TiO_2	0,36 %
P_2O_5	27,03 %
ThO_2	10,50 %
U_3O_8	0,04 %
$(RE)_2O_3$	61,57 %

Rajendran et al. 2008

REO Composition	
Lanthanum	23,05 %
Cerium	31,74 %
Praseodymium	6,59 %
Neodymium	20,37 %
Samarium	6,95 %
Gadolinium	4,74 %
Yttrium	6,56 %
Dysprosium Europium Terbium:	*traces*

Soe et al. 2008

Monazite crystal

Rare Earths: Mineralogy

Typical REO-Distribution in Bastnaesite $LnFCO_3$

Lanthanum	33,2 %
Cerium	49,1 %
Neodymium	12,1 %
Praseodymium	4,3 %
Samarium	0,8 %
Gadolinium	0,2 %
Europium	*0,1 %*
Dysprosium and Terbium:	*traces*

Bastnaesite crystals

Rare Earths: Deposits

Geological Settings

- **Peralkaline** intrusive rock deposits ($Na_2O+K_2O>Al_2O_3$), such as quartz poor pegmatite and syenite, are typically enriched in Y and HREE and contain lesser amount of LREE such as Avalon Rare Elements recent Thor Lake/Nechalacho REE Project, Canada.
- **Carbonatites** are igneous rocks composed of more than 50% carbonate minerals, predominantly calcite and dolomite. Carbonatite occurs commonly as intrusive bodies, dikes or veins in the host rock and are rich in LREE (e.g. Mountain Pass, US).
- Lateritic Deposits: The ore, referred to as REE-bearing **ionic adsorption clay**, mostly comes from two districts in the Jiangxi Province, Longnan and Xunwu, the former yielding exceptional HREE- and Yttrium-rich material and the other, LREE-rich material.
- **Placer** rutile-zircon-ilmenite deposits found in India, Malaysia, Sri Lanka, Thailand, Australia and Brazil produce Monazite concentrates.
- The world largest source (Bayan Obo, China) is a giant **polymetallic Iron-Niob-REE deposit** now regarded as a hydrothermal carbonate replacement, formed within sedimentary rocks (shale and marble) during a duration of 150 Mio years.

Rare Earths: Deposits

The Sedimentary Carbonate-Hosted Giant Bayan Obo REE-Fe-Nb Ore Deposit

- The Bayan Obo deposit is situated in Inner Mongolia (China) 135 km northwest of Baotou.
- It is a giant polymetallic rare earth element (REE)-Fe-Nb ore deposit of hydrothermal origin and is now the most important REE source in the world.
- The total reserves have been reported as at least 750 Mt with an average grade of 4,1% REO.
- High LREE/HREE ratio.

Mining activity at the Bayan Obo Deposit (Google).

Rare Earths: Deposits

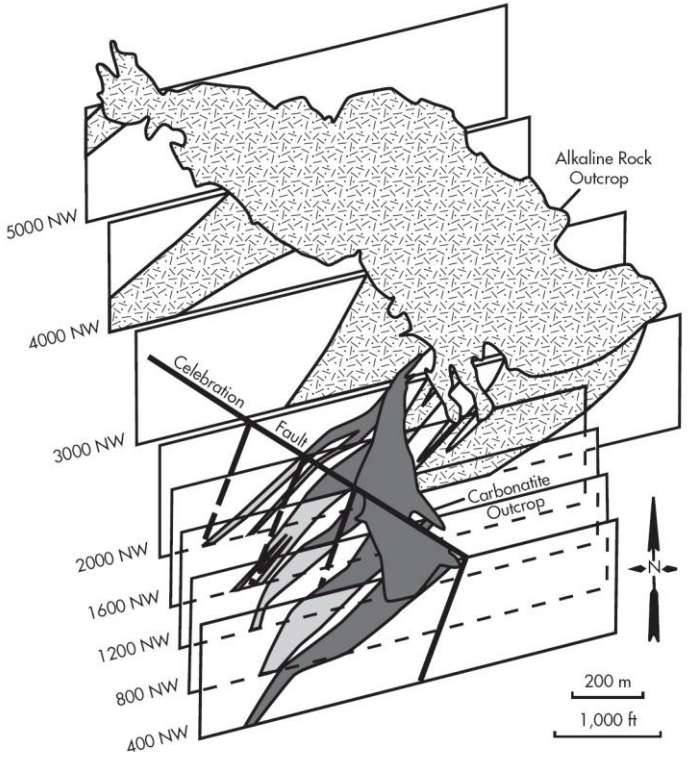
Carbonatites: The Mountain Pass Deposit in California

- Worldwide more than 100 carbonatite occurences that contain REE minerals are listed.
- REEs were mined in the Mountain Pass destrict in California from 1952 to 2002.
- The proven and probable reserves at the open-pit mine at Mountain Pass total to 29 Mt with an average concentration of 8,24% REO (USGS).
- Mountain Pass was discovered in the course of a USGS radioactivity survey that expected to find Uranium.
- Mountain Pass operations came under pressure after a 1996 wastewater spill. Mining there ceased in 2002 when **Molycorp's** old permit expired.
- The reserve could provide LREE in sufficient quantities to supply current US demand of 20,000 tpy for the next 100 years.

Rare Earths: Deposits

Mountain Pass: Geological Setting

- At Mountain Pass the ore typically contains 10-15% **bastnaesite**, 65% calcite or dolomite and 20-25% barite.
- A stacked cross sections through the Mountain Pass deposit indicates the REE carbonatite ore body (gray) and a major associated alkaline rock mass (patterned). The deposit has been dated at 1,4 Ga.
- Carbonatites typically have high LREE/HREE ratios.
- The mine is supposed to hold negligible traces of uranium and thorium – two radioactive elements often found together with rare earths that can make recovery of them more costly.



Stephen B. Castor and James B. Hedrick: Rare Earth Elements (2004)

Rare Earths: Deposits

Laterite (ionic absorption) clay deposits

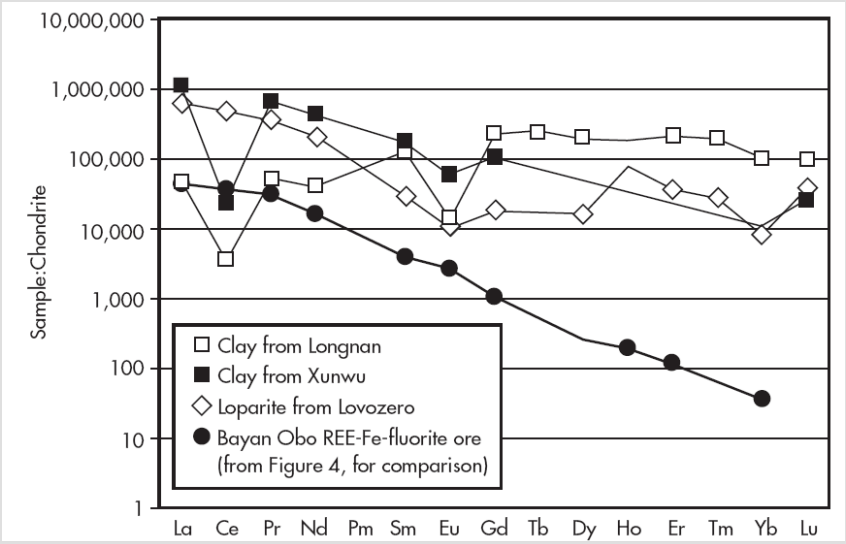
- Most of China's HREE production comes from about 200 mines in south-east China (Guangdong and Jiangxi Province).
- The most important deposits today – Longnan and Xunwu form weathering crusts over granite.
- Both ores have low Cerium content, suggesting deposition from REE-bearing groundwater.

This abandoned mine in Guyun Village in south eastern China exhausted the local deposit of heavy rare-earth elements in three years.
http://www.nytimes.com/2009/12/26/business/global/26rare.html?_r=1&pagewanted=1&hp

Rare Earths: Deposits

Laterite (ionic absorption) clay deposits

- The ore bodies are 3 to 10m thick rich in kaolinite and halloysite with grades ranging from 0,05-0,2% REO.
- Ore from Longnan deposit has an HREE-dominated distribution pattern, whereas ore from Xunwu is enriched in lanthanum.

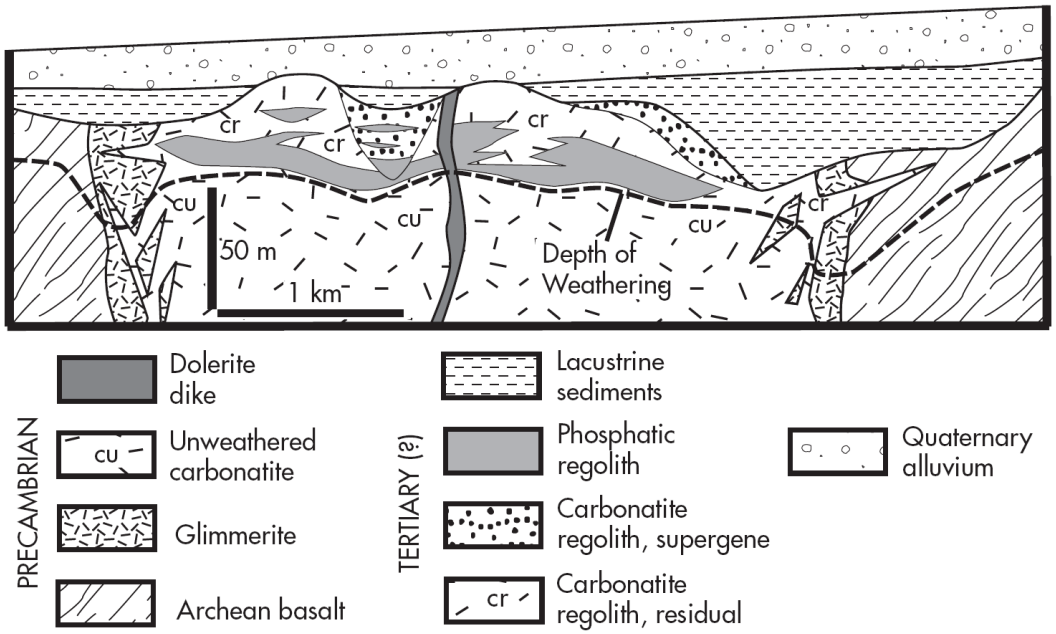


Chondrite-normalized plot of REE distribution (normalized to 100%) in ion absorption clay and Bayan Obo ores from China and loparite from Russia (Castor & Hedrick 2006, data source: Hedrick 1992)

Rare Earths: Deposits

Mount Weld carbonatite and weathered laterite cap

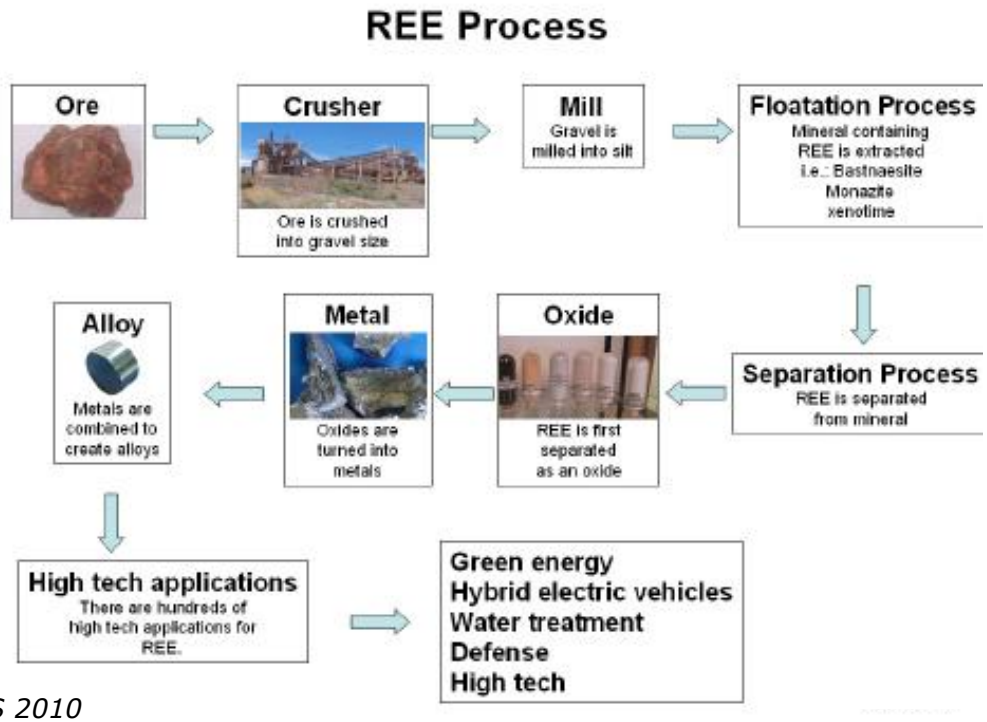
- The **Mount Weld** REE deposit in Western Australia is in the laterized cap over a large carbonatite.
- Although LREE/HREE ratios are generally high, the laterite is locally enriched in HREEs and Yttrium.
- Published reserve figures by Lynas are 15.0 Mt with 11.2% REOs + Y_2O_3, and 2.1 Mt with 15.5% REOs (USGS).



Rare Earths: Processing

Value Chain in REE processing

- Mining of host rock where the ore is crushed and blended in stockpiles
- Separation of mineral concentrates (+60% REO).
- Acid leaching, REE extraction and precipitation processes.
- Separation of specific REO compounds by fractional crystallization, solvent extraction, ion exchange.
- Electrolytic reduction and final purification to metals

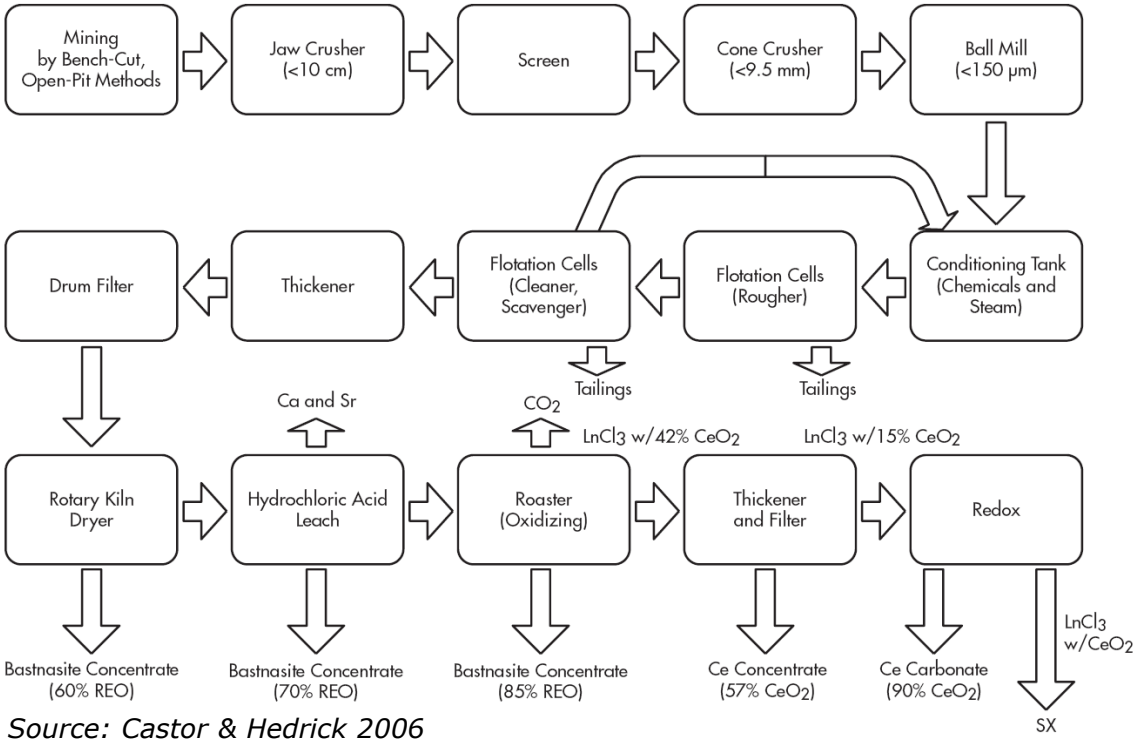


Source: IAGS 2010

Rare Earths: Processing

Bastnasite: Minerals Concentration and REO Extraction (Mountain Pass, California)

- Mechanical Liberation
  crushing, milling, scrubbing, drying, screening
- Physical separation
  flotation, electrostatic, magnetic, gravity separation or processes
- Chemical extraction
  acid leaching, digestion, roasting, hot chlorination (loparite) or baking

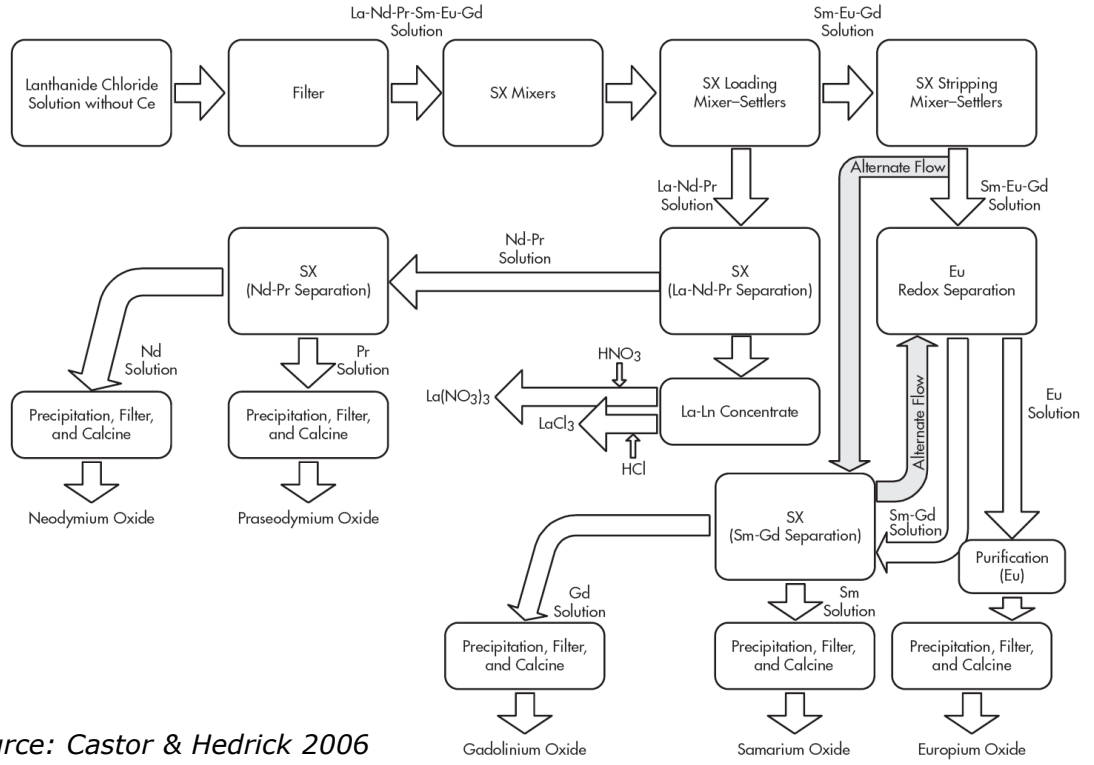


Source: Castor & Hedrick 2006

Rare Earths: Processing

Rare earth SX flow diagram (Mountain Pass, California)

- Separation of specific REO compounds
  fractional crystallization, solvent extraction (SX), ion exchange

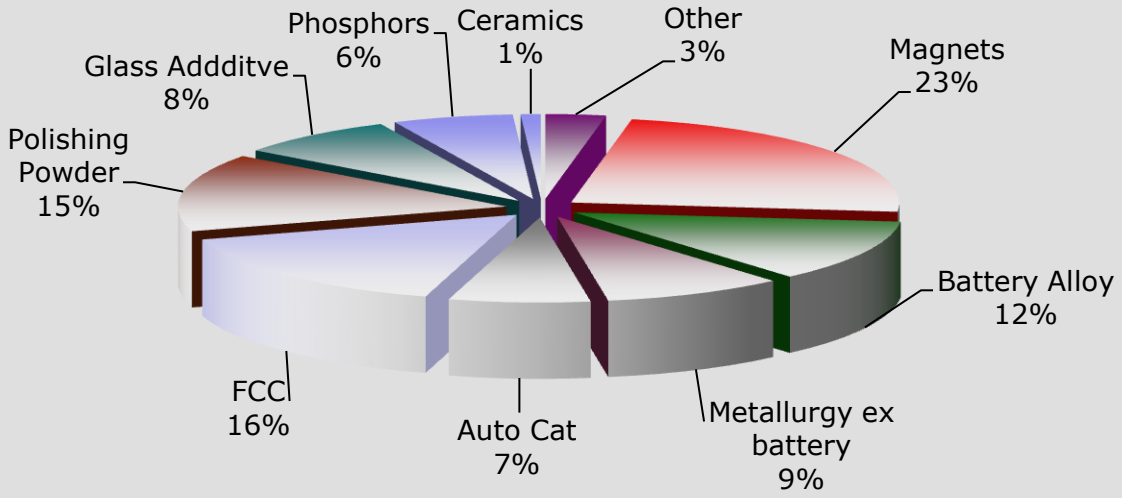


Source: Castor & Hedrick 2006

Rare Earths: Demand

2010 by Application

- Rare Earth Elements (REE) are used in a wide variety of high tech industrial applications, including the manufac-ture of batteries, magnets, catalytic converters, and computer display screens.
- Demand has surged by green energy applica-tions (e.g. wind turbines, compact fluorescent bulbs). The current 3rd-generation hybrid Toyota Prius uses 11 kg of rare earth metals.



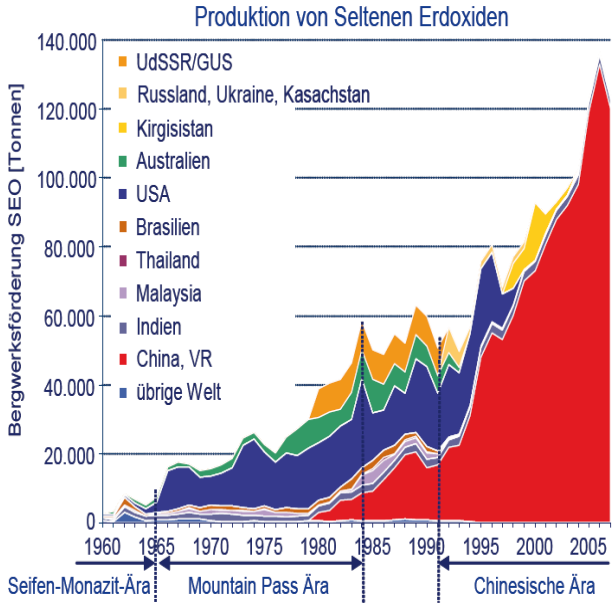
Total = 134,000 tonnes REO

Source: Lynas Co. MMTA April 2010

Rare Earths: Supply

China dominates

- During the first half of the 20th century, REEs came mainly from **placer deposits**, particularly those of the south-eastern United States.
- Between 1965 and 1985, most of the world's REEs came from **Mountain Pass**, California.
- During the 1980s, China emerged as a major producer of REE raw materials, accounting for more than 95% of the world's REE raw materials, and most of this production is from the **Bayan Obo** deposit.

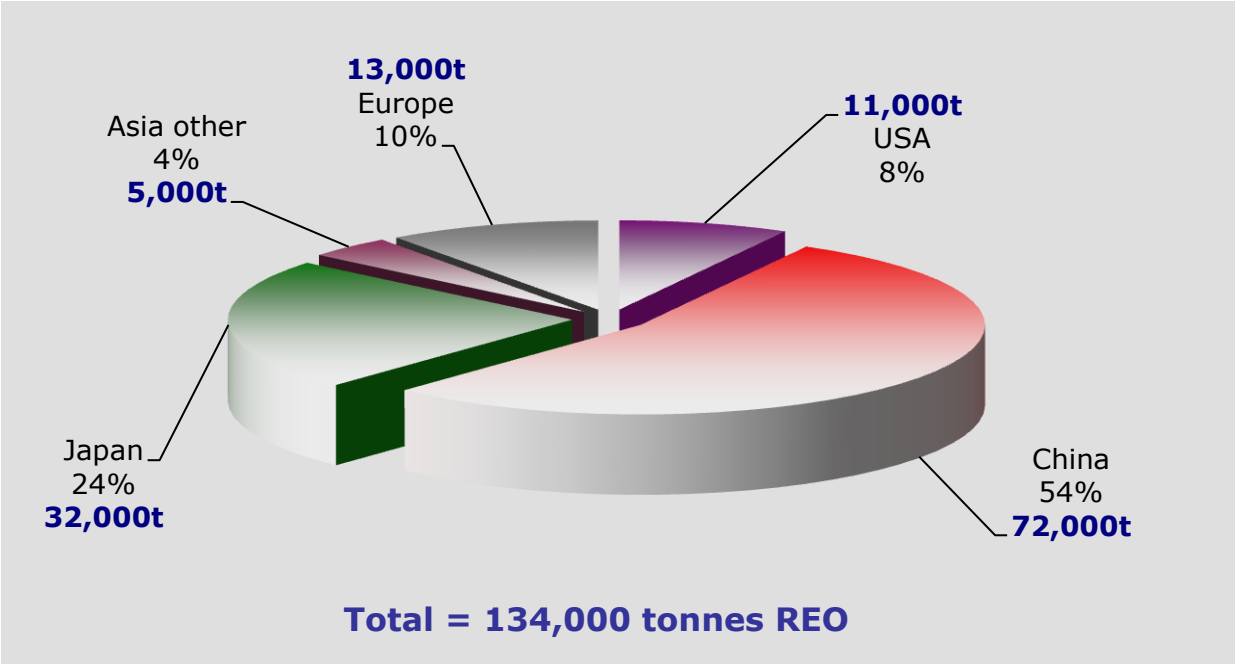


Source: BGR, 2009

Rare Earths: Demand

2010 by Region

- It is important to realize that the situation regarding the supply security of rare earth supply elements has been fundamentally driven by China's growing domestic demand.

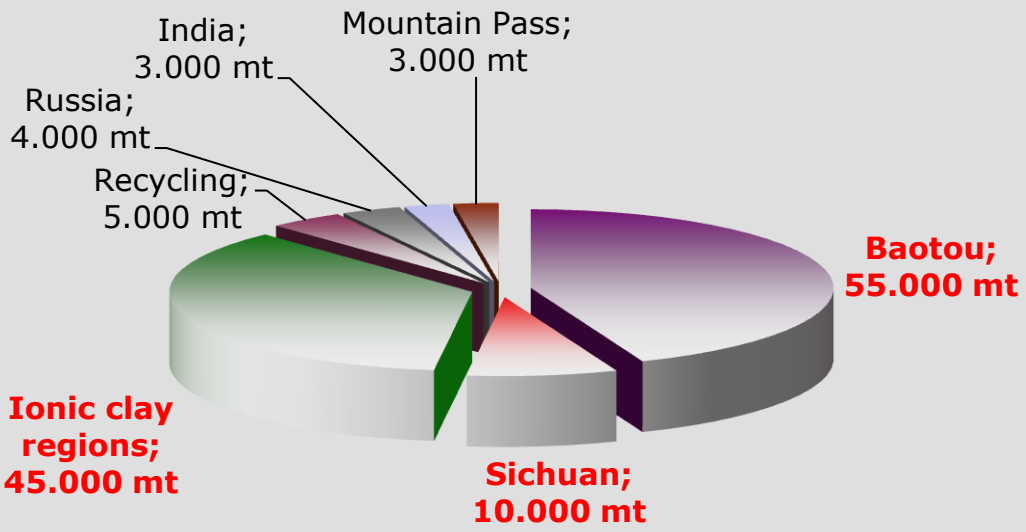


Source: Roskill 2008 / Lynas Co. MMTA April 2010

Rare Earths: Supply

2010 by REO capacity

- India and Brasil producing TREO from heavy mineral sands.
- Russia processes Loparite concentrates at Lovozero.
- Mountain Pass recovers mineral concentrates from stockpiled raw materials.



Total = 125,000 tonnes REO

Source: USGS SIR5220, 2010

Rare Earths: Supply

The China Factor

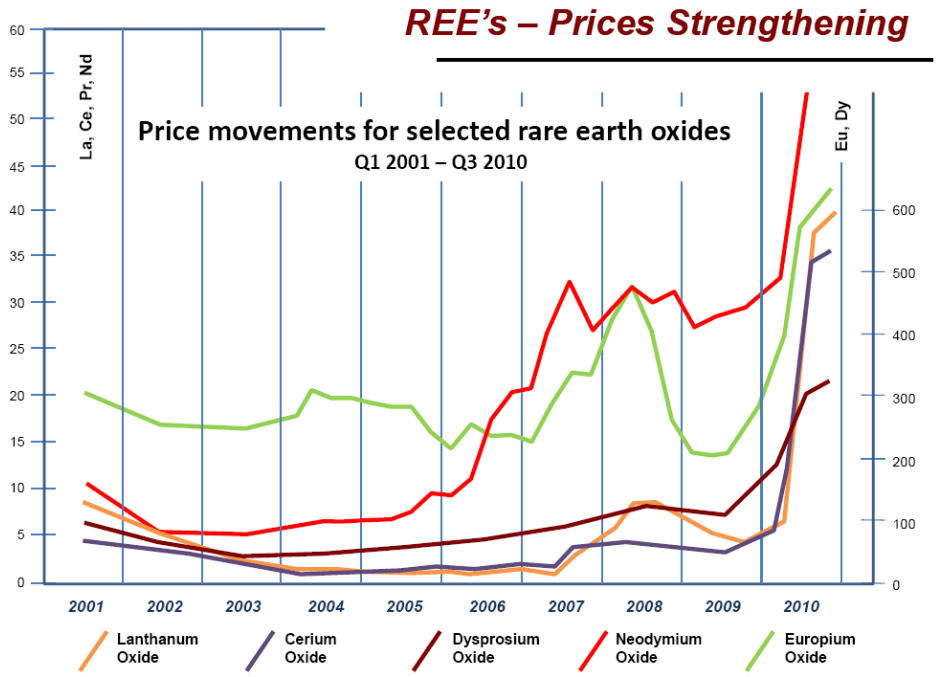
- The export quotas for 2010 total to 30,258 tons, cut by 40% compared to 2009.
- Export Taxes steadily increase:
  2009 LREE & Nd-Metal 15%, HREE 25%.
- September 2010 export embargo to Japan.

Source: IMCOA

Rare Earths: Supply

The China Factor

- Late 2010 saw prices for Lanthanum oxide increase nearly fourfold and for Cerium oxide almost five times as buyers outside China have seen price rises across the board.



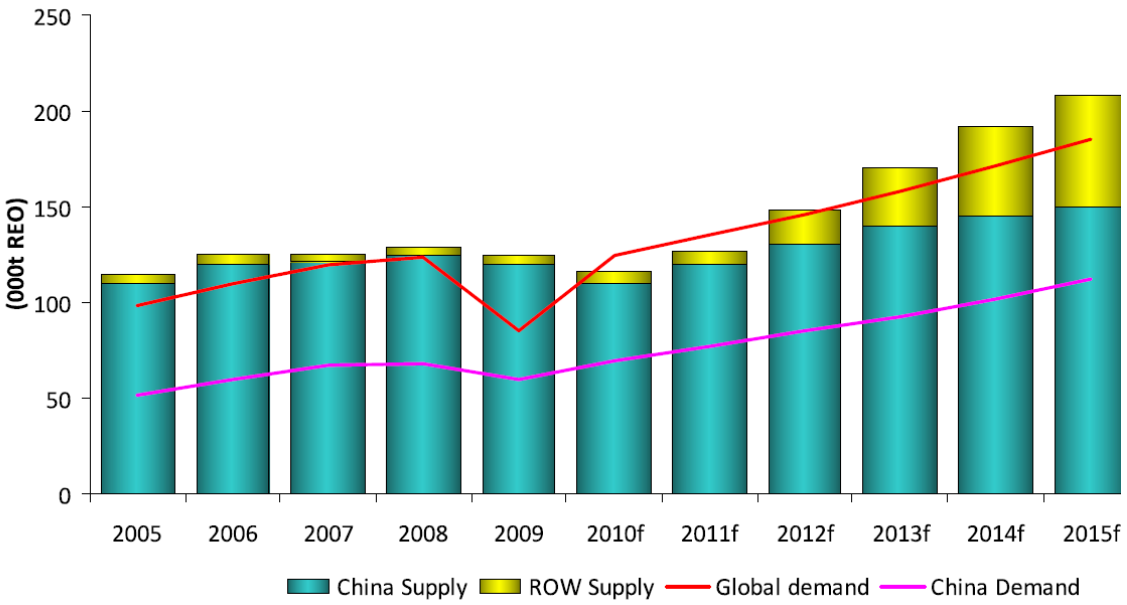
Source: Metal Pages

Rare Earths: Demand

China dominates

Forecasted demand reaches **180.000 to 210.000 t/a** REO in 2015 with China consuming almost all of its current production.

The worldwide gap to current production capacity of 120.000 t/a is expected to be closed by new capacities from outside China.



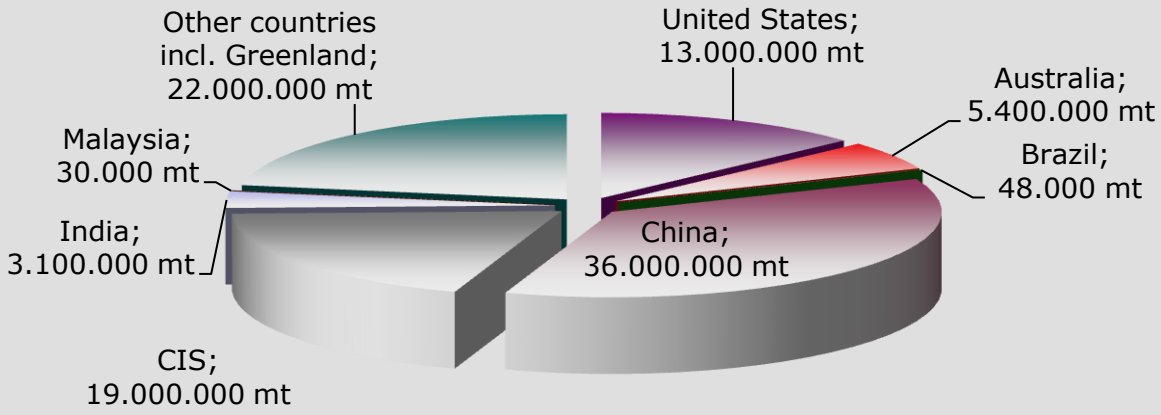
Text Source: BUNDESANSTALT FÜR GEOWISSENSCHAFTEN UND ROHSTOFFE 2009

Source: Roskill/IMCOA 2010

Global Reserves of Rare Earths

2010 by U.S. Geological Survey (USGS)

- The USGS estimates global reserves are 99 Mt with 36% of those reserves in China, 19% in the Commonwealth of Independent States (CIS), 13% in the U.S., 5% in Australia, 0.05% in Brazil, and 22% in other countries (e.g. Greenland).
- China holds only 36% of known reserves but 90% of production capacity.



World total = 99,000,000 tonnes REO

U.S. Geological Survey, Mineral Commodity Summaries, January 2010

Rare Earth: Deposits

Major deposits world wide

Location No.	Location Name	Deposit Type
1	Bayan Obo, China	Fe-REE-Nb deposit
2	Weishan, China	Bastnasite-barite veins
3	Maoniuping, China	Bastnasite-barite veins
4	Xunwu and Longnan, China	Lateritic clay
5	Chavara, India	Monazite by-product, coastal placers
6	Perak, Malaysia	Xenotime by-product, tin placers
7	Mountain Pass, USA	Bastnasite-barite carbonatite
8	Lovozero, Russia	Loparite in peralkaline complex
9	Aktyus, Kyrgyzstan	Polymetallic deposit
10	Northern Sri Lanka	Monazite by-product, coastal placers

Location No.	Location Name	Deposit Type
11	Orissa, India	Monazite by-product, coastal placers
12	Eneabba, Australia	Monazite by-product, coastal placers
13	Capel and Yoganup, Australia	Monazite by-product, coastal placers
14	Mount Weld, Australia	Lateritized carbonatite
15	Dubbo, Australia	Altered alkaline complex
16	North Stradboke Island, Australia	Monazite by-product, coastal placers
17	Elliot Lake, Canada	Uraniferous conglomerate
18	Green Cove Springs, USA	Monazite by-product, placer
19	Camaratuba, Brazil	Monazite by-product, coastal placers
20	Steenkampskraal, South Africa	Monazite-apatite vein

Source: Castor & Hedrick 2006

Rare Earth: Deposits

Selected projects outside China

- (1) Lynas Corp., (2) Molycorp Minerals, (3) (4) Great Western Minerals, (5) Alkane Resources, (6) Vietnamese govt./Toyota Tsusho/Sojitz, (7) Arafura Resources, (8) Avalon Rare Metals, (9) Kazatomprom/ Sumitomo, (10) Stans Energy, (11) Greenland Minerals and Energy, (12) Rare Element Resources, (13) Pele Mountain Resources, (14) Quest Rare Metals, (15) Ucore Uranium, (16) US Rare Earths, (17) Matamec Explorations, (18) Etruscan Resources, (19) Montero Mining, (20) Tasman Metals, (21) Neo Material Technologies/Mitsubishi

- *Selected European deposits:*
  Saxonia (Deutsche Rohstoff AG; TREO 0,5%), Scandinavia (Tasman Metals; u.a. Norra Kärr 0,4-0,6%, Korsnas 0,8%), Portugal (0,5%), Turkey (Province Eskisehir, W-Turkey), Lovozerskaya GOK (Russland, aktiv), Greenland (Greenland Minerals, 1,1%)

Source: IM June 2010 and ANZAPLAN

Rare Earths: … and many more to come

Over 200 REE Projects identified by Mid 2010
Selected TSX and TSX Venture Companies

African Aura Mining Inc.,
Altius Minerals Corp.,
Argus Metals Corp.,
Arianne Resources Inc.,
Aurizon Mines Ltd.,
Avalon Rare Metals Inc.,
Azimut Exploration Inc., …

Benton Resources Corp.,
Big Red Diamond Corp., …

Canadian Orebodies Inc.,
CanAlaska Uranium Ltd.,
Capella Resources Ltd.,
Commerce Resources Corp.,
Consolidated Abaddon Resources Inc.,
Cornerstone Capital Resources Inc.,
Cream Minerals Ltd., …

Eagle Plains Resources Ltd.,
Etruscan Resources Inc., …

Fieldex Exploration Inc.,
First Lithium Resources Inc.,
Forum Uranium Corp., …

Galahad Metals Inc.,
Globex Mining Enterprises Inc., …
Gold Canyon Resources Inc.,
Golden Dory Resources Corp., …
Goldstake Explorations Inc., …
Great Western Minerals Group Ltd., …

Hinterland Metals Inc.,
Hudson Resources Inc.,
International Montoro Resources Inc.,
JNR Resources Inc.,
Jourdan Resources Inc., …

Kings Bay Gold Corp.,
Kirrin Resources Inc.,

Source: http://www.cbc.ca/money/story/2010/02/12/f-rare-earth-rush.html

Rare Earths: … and many more to come

Over 200 REE Projects identified by Mid 2010
Selected TSX and TSX Venture Companies

Kings Bay Gold Corp.,
Kirrin Resources Inc., …

Mainstream Minerals Corp.,
Matamec Explorations Inc.,
Mawson Resources Ltd.,
Medallion Resources Ltd.,
Midland Exploration Inc., …

Niogold Mining Corp.,
Nortec Minerals Corp.,
Nuinsco Resources Limited,

Otish Energy Inc., …

Paget Minerals Corp.,
Pele Mountain Resources Inc., …

Playfair Mining Ltd.,
Pure Nickel Inc., …

Quest Uranium Corp., …

Rare Earth Metals Inc.,
Rare Element Resources Ltd.,
Red Hill Energy Inc.,
Rock Tech Resources Inc.,
Rubicon Minerals Corp., …

Silver Fields Resources Inc.,
Slam Exploration Ltd.,
Sparton Resources Inc.,
Stans Energy Corp.,
Stelmine Canada Ltd.,

Stratabound Minerals Corp.,
Strategic Resources Inc., …

Tasman Metals Ltd.,
Threegold Resources Inc.,
TNR Gold Corp.,
Torch River Resources Ltd.,
True North Gems Inc., …

Ucore Uranium Inc.,
Victoria Gold Corp.,
VMS Ventures Inc., …

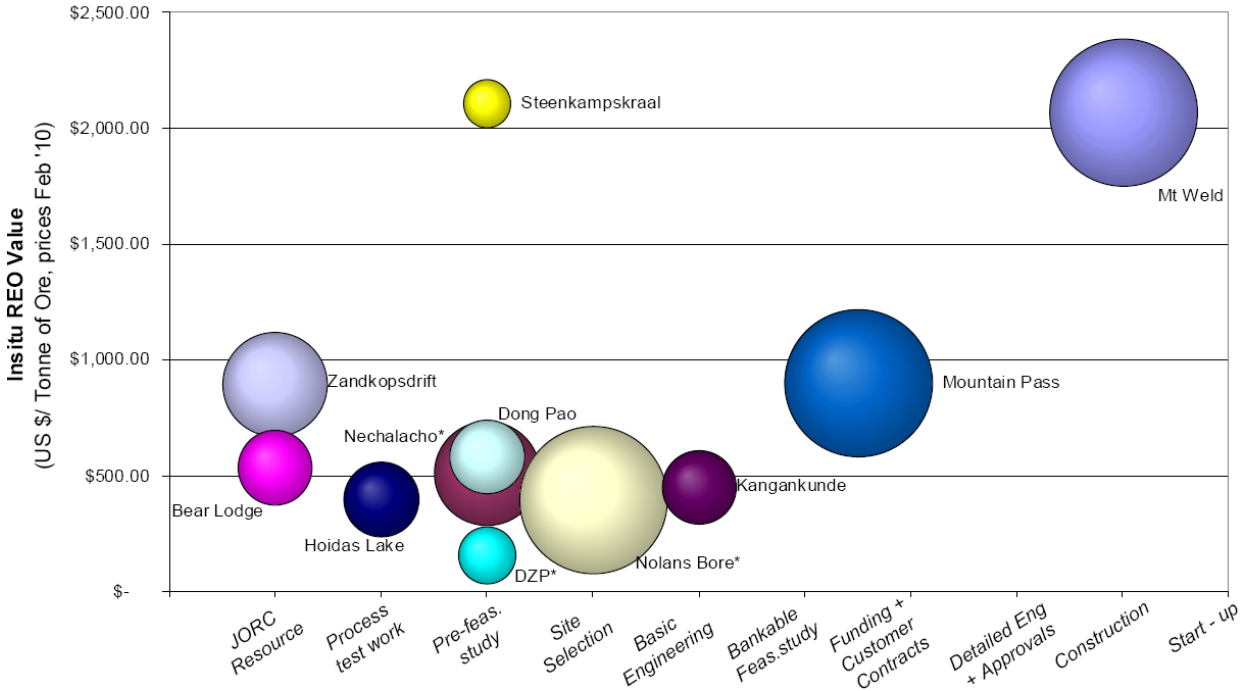
Waterloo Resources Ltd.,
Western Troy Capital Resources Inc., …

Yankee Hat Minerals Ltd. …

Rare Earths: New Entrants

Developed Projects

- Besides the Mount Weld and Mountain Pass deposits there are several projects under development.
- However, the majority of deposits already working on feasibility stages are **rich in LREEs**.



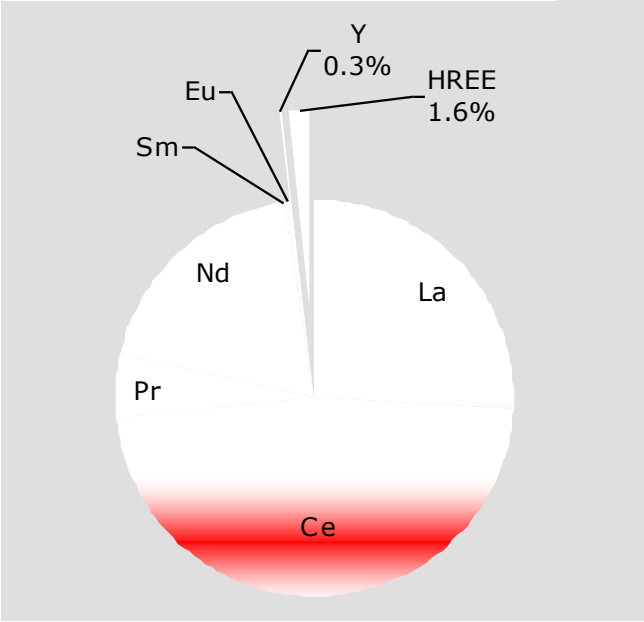
*) *Bubble Size represents stated production volume*

Source: Lynas Co. MMTA April 2010

Rare Earths: New Entrants

The most advanced projects: Mt Weld, W-Australia by Lynas (under construction)

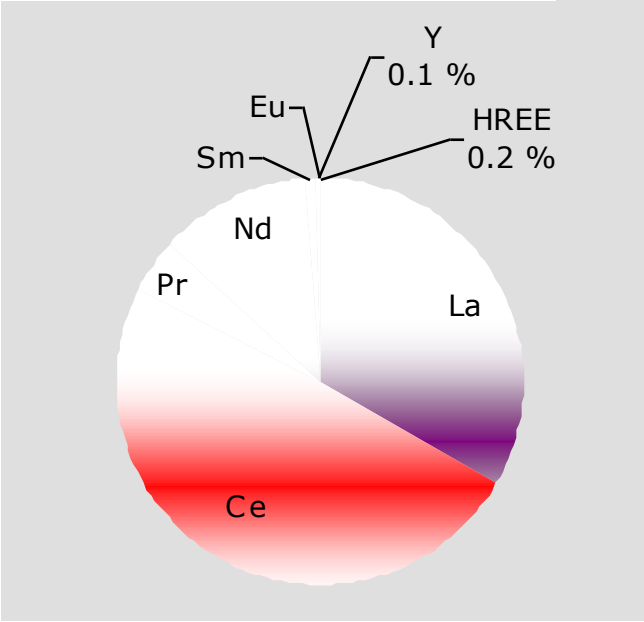
- Mount Weld deposit, Western Australia
- Processing plant in Gebeng, Malaysia, under construction
- Resource of 17.49Mt at 8.1% REO, equivalent to 1.42Mt REO
- Concentrator will produce 35ktpy of concentrate grading 40% REO
- Phase 1 at Gebeng plant (Malaysia) has the capacity to produce 10,500tpy REO
- **Start up in Gabeng planned for late 2011**, full production by 2012



Rare Earths: New Entrants

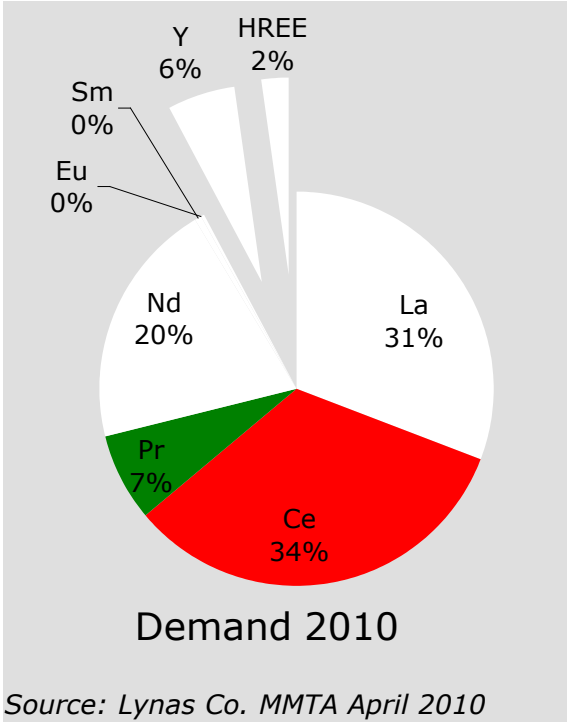
The most advanced projects: Mountain Pass, USA by Molycorp

- Over 50 years of production history at Mountain Pass, California, USA
- Proven reserves 40,000t of REO contained in 0.48Mt or at average grade of 9.38%
- Probable reserves of 960,000t of REO in 13.8Mt or at average grade of 8.2%
- Production of REOs at the rate of 19,090tpy **by Mid 2012**.

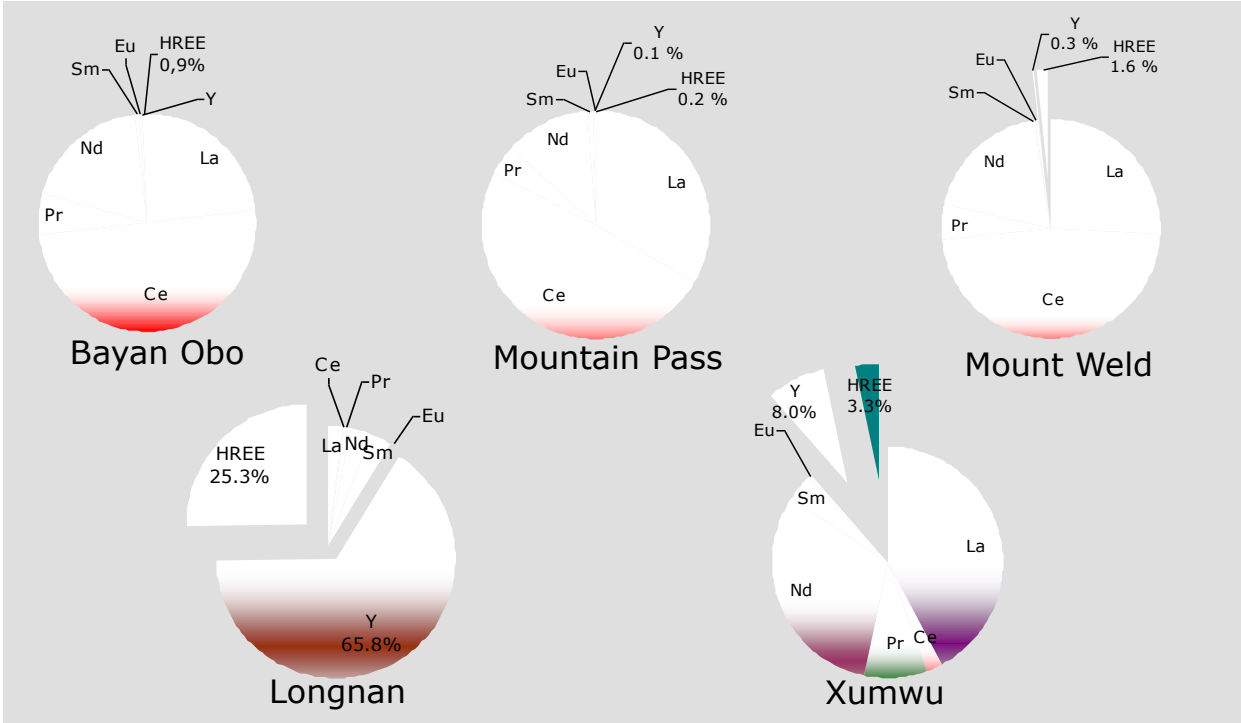


Rare Earths: Demand

Selective demand difficult to balance 2010 - 2015



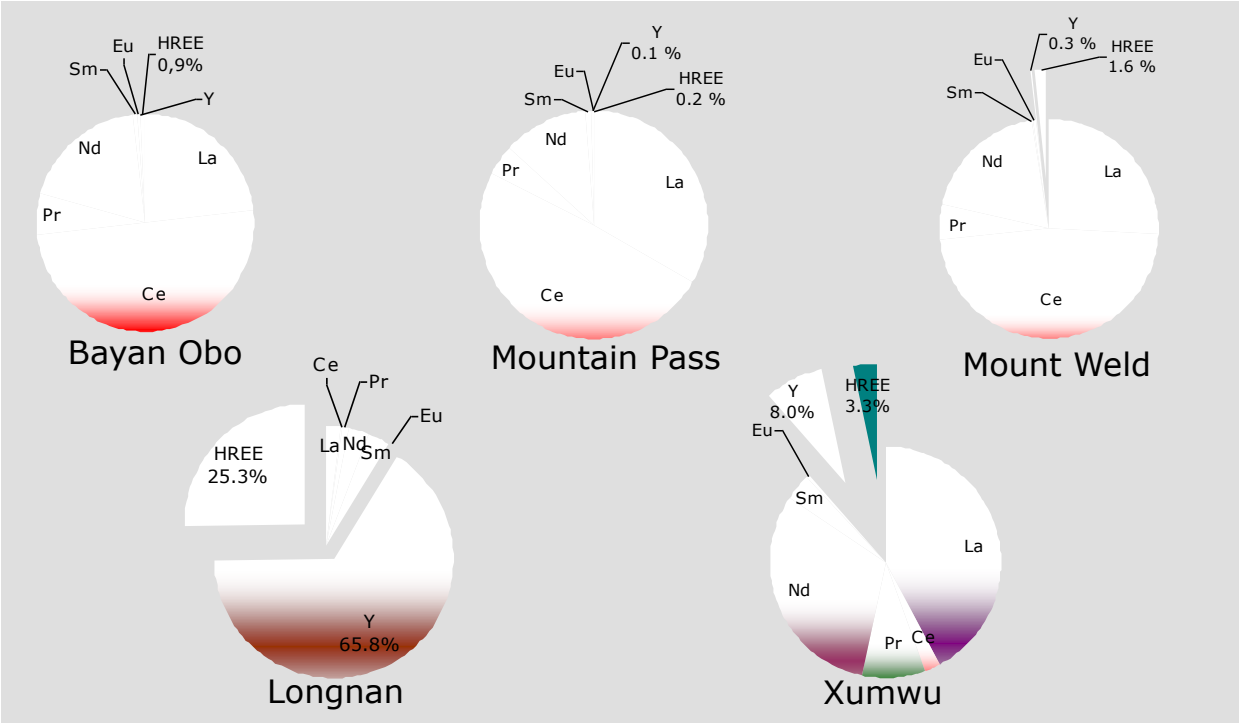
Source: Lynas Co. MMTA April 2010



Rare Earths: Demand

Selective demand difficult to balance 2010 - 2015

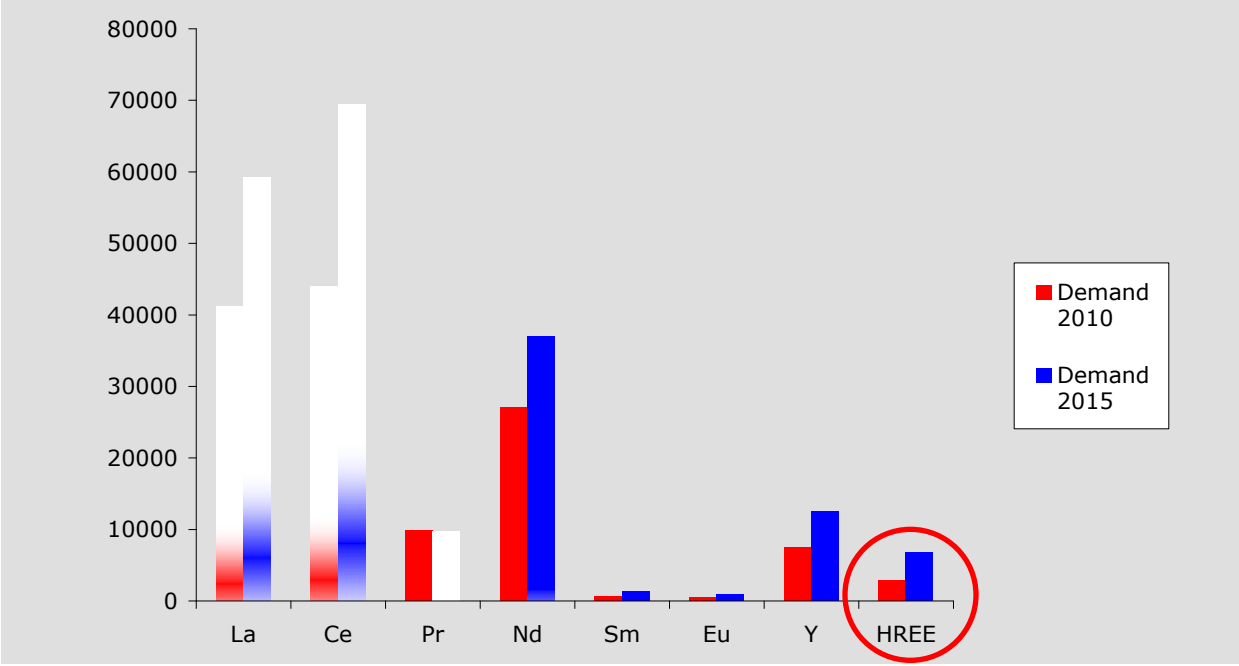
- Ratio of natural occur-rence in most of the deposits **does not match the demand** of the market, leading to a supply/demand imbalance even with increasing production.
- **Finite HREE** resources in China (mine live 15-20 years).



Rare Earths: Demand

Selective demand difficult to balance 2010 - 2015

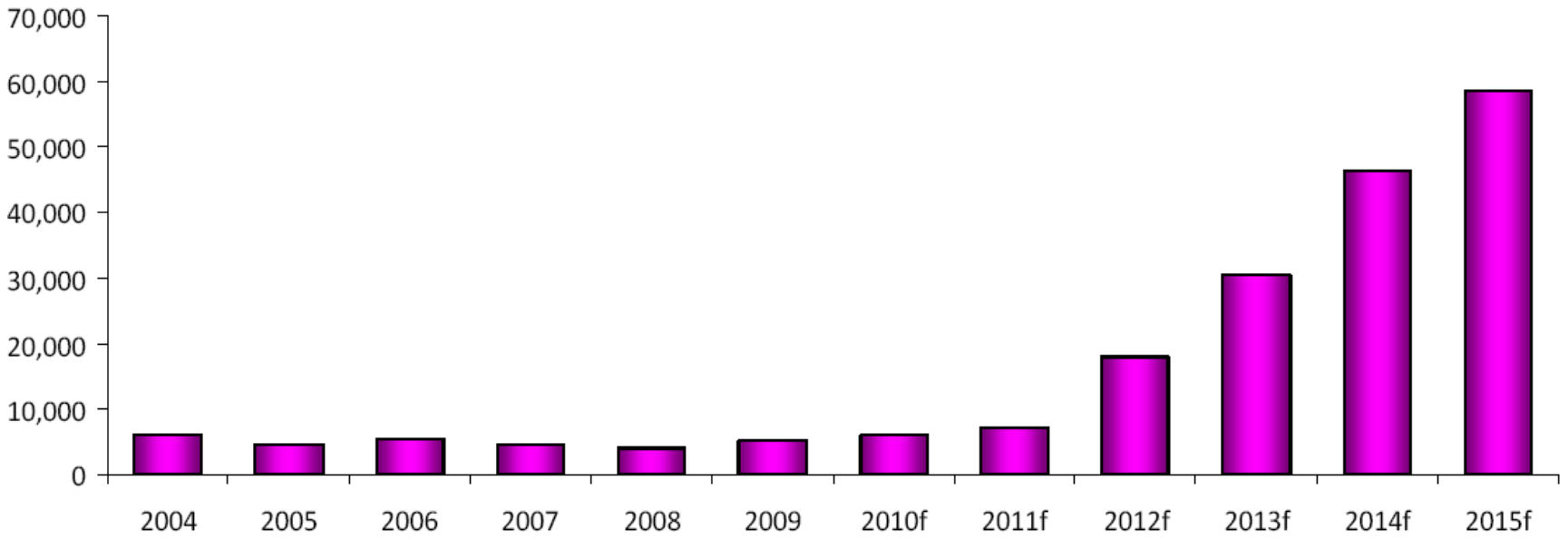
- By 2015 there are expected to be **shortages of HREE**, due to more than double in demand from end markets and limited balance of these elements by the new deposits.
- Neodymium, Terbium and Dysprosium (for high strength magnets) and Europium (flat screens) could be lacking, while Lanthanum and **Cerium will face oversupply** by new entrants.



Source: IM June 2010

Rare Earths: ROW is closing the gap ?

ROW mine production of REO, 2004 – 2015



Source: Roskill Rare Earth Summit 2010

Rare Earths: New Entrants

The search for heavy rare earths

- **Alkane Resources, Australia**
  Proposed production of HREEs as by-product of zirconium production at Dubbo, NSW, Australia.
- **Avalon Rare Metals Inc., Canada**
  Nechalacho deposit rich in HREEs in NWT, Canada, however low ore grade overall (176Mt at 1,43% REO) but high ratio of heavies.
- **Quest Rare Metals, Canada**
  High proportion of HREEs in Strange Lake.
- **Greenland Minerals & Energy Ltd., Kvanefjeld**
  May become the largest deposit outside China.
- **Tantalus Rare Earths AG**
  Crop sampling in northern Madagascar indicates a favourable ratio of heavy rare earth elements

Backward Integration and Tailings Processing

- **Toyota group/Indian Rare Earths (IRE) JV**
  New monazite processing plant in Orissa with a capacity of 4,000tpy concentrate previously subject to local opposition.
- **Sumitomo/Kazatomprom**
  SARECO JV plans to build refinery to treat Y-rich uranium ore tailings, uranium ores and rare earth concentrates to produce REOs and RE metals.
  However – still the subject of a feasibility study.
- **Mitsubishi/Neo Material Technologies**
  Undertaking research to extract HREEs from tailings at Mineracao Taboca´s Sn, Ta and Nb mine at Pitinga, Brazil. Tailings reported to contain 8.5% REO – with a high grade of Dysprosium. In addition to Neo's Pitinga project, Mitsubishi and Neo will continue to collaborate on the identification and development of rare earth resources around the globe.

Summary

The Disclosure for Mineral Projects

- Main commercial REE-Minerals are Bastnaesite, Monazite, Loparite, Eudialite, Steenstrupine and Ion Adsorption Clays; REO concentration in most deposits is low (0,2 – 3%).
- Percentage REO content is only half the story – REO distribution (fit to demand) and mineralogy (processing and extraction) are important.
- Developing a rare earth mine, mineral concentration plant and REO processing plant is highly capital intensive (>US$50,000/t capacity), e.g. Avalon Rare Metals capital cost is US$ 810 Mio for 10.000 tpy REO capacity, Kvanefjeld US$ 2.31 billion at nominal 40.000 tpy REO.
- Only two projects (Mountain Pass and Mt. Weld) are beyond the stage of a feasibility study. It should be noted that REE projects require many years of metallurgical testing and development.
- Many deposits contain radioactive material that has to be contained and stored – a cost rather than a benefit for the moment.
- Limited technical expertise on mining, extraction and separation outside China.

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Thank you!