



The Future of Rare Earth Elements— Will These High-Tech Industry Elements Continue in Short Supply?

By Keith R. Long

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Image of pure rare earth elements oxides from:

<http://seeker401.wordpress.com/2010/11/18/experts-speak-about-a-rare-earth-bubble/>.

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PERIODIC TABLE OF THE ELEMENTS

| | | | | | | | | | | | | | | | | | |
|----------------------|-----------------------|-----------------------------------|----------------------------|----------------------|-------------------------|------------------------|-----------------------|-------------------------|-------------------------|--------------------|---------------------|-----------------------|-----------------------|-----------------------|-----------------------|----------------------|---------------------|
| 1 H Hydrogen | | | | | | | | | | | | | | | | | 2 He Helium |
| 3 Li Lithium | 4 Be Beryllium | | | | | | | | | | | 5 B Boron | 6 C Carbon | 7 N Nitrogen | 8 O Oxygen | 9 F Fluorine | 10 Ne Neon |
| 11 Na Sodium | 12 Mg Magnesium | | | | | | | | | | | 13 Al Aluminium | 14 Si Silicon | 15 P Phosphorus | 16 S Sulphur | 17 Cl Chlorine | 18 Ar Argon |
| 19 K Potassium | 20 Ca Calcium | 21 Sc Scandium | 22 Ti Titanium | 23 V Vanadium | 24 Cr Chromium | 25 Mn Manganese | 26 Fe Iron | 27 Co Cobalt | 28 Ni Nickel | 29 Cu Copper | 30 Zn Zinc | 31 Ga Gallium | 32 Ge Germanium | 33 As Arsenic | 34 Se Selenium | 35 Br Bromine | 36 Kr Krypton |
| 37 Rb Rubidium | 38 Sr Strontium | 39 Y Yttrium | 40 Zr Zirconium | 41 Nb Niobium | 42 Mo Molybdenum | 43 Tc Technetium | 44 Ru Ruthenium | 45 Rh Rhodium | 46 Pd Palladium | 47 Ag Silver | 48 Cd Cadmium | 49 In Indium | 50 Sn Tin | 51 Sb Antimony | 52 Te Tellurium | 53 I Iodine | 54 Xe Xenon |
| 55 Cs Caesium | 56 Ba Barium | 57-71 Lanthanides see below | 72 Hf Hafnium | 73 Ta Tantalum | 74 W Tungsten | 75 Re Rhenium | 76 Os Osmium | 77 Ir Iridium | 78 Pt Platinum | 79 Au Gold | 80 Hg Mercury | 81 Tl Thallium | 82 Pb Lead | 83 Bi Bismuth | 84 Po Polonium | 85 At Astatine | 86 Rn Radon |
| 87 Fr Francium | 88 Ra Radium | 89-103 Actinides see below | 104 Rf Rutherfordium | 105 Db Dubnium | 106 Sg Seaborgium | 107 Bh Bohrium | 108 Hs Hassium | 109 Mt Meitnerium | 110 Uu Ununnilium | | | | | | | | |

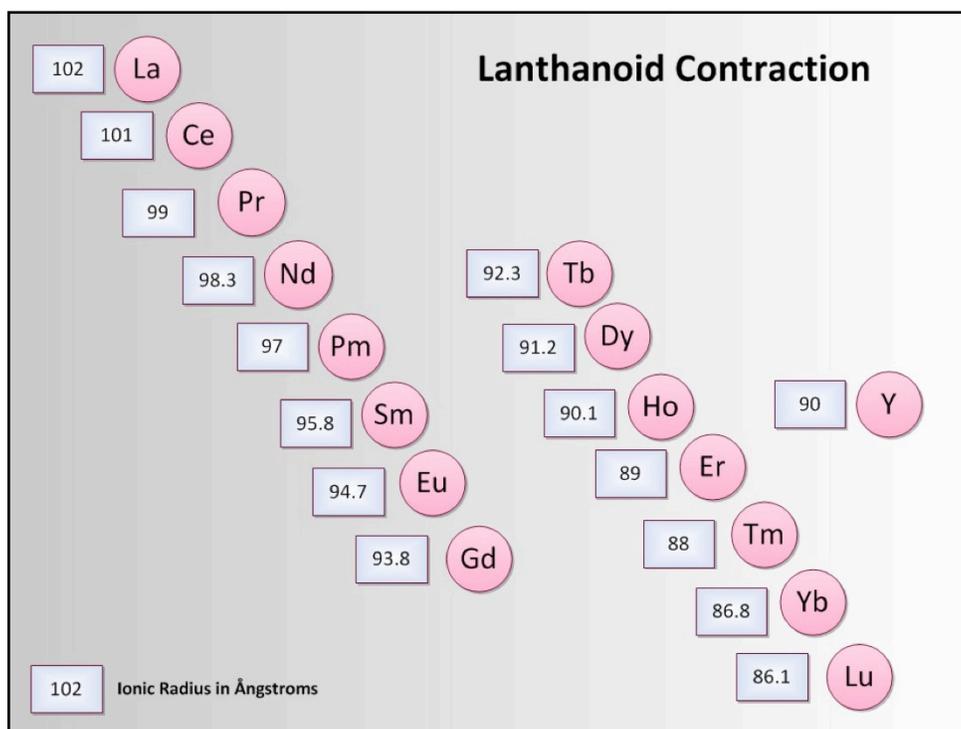
| | | | | | | | | | | | | | | |
|-----------------------|---------------------|--------------------------|-----------------------|------------------------|-----------------------|-----------------------|------------------------|-----------------------|-------------------------|-------------------------|----------------------|--------------------------|-----------------------|-------------------------|
| 57 La Lanthanum | 58 Ce Cerium | 59 Pr Praseodymium | 60 Nd Neodymium | 61 Pm Promethium | 62 Sm Samarium | 63 Eu Europium | 64 Gd Gadolinium | 65 Tb Terbium | 66 Dy Dysprosium | 67 Ho Holmium | 68 Er Erbium | 69 Tm Thulium | 70 Yb Ytterbium | 71 Lu Lutetium |
| 89 Ac Actinium | 90 Th Thorium | 91 Pa Protactinium | 92 U Uranium | 93 Np Neptunium | 94 Pu Plutonium | 95 Am Americium | 96 Cm Curium | 97 Bk Berkelium | 98 Cf Californium | 99 Es Einsteinium | 100 Fm Fermium | 101 Md Mendelevium | 102 No Nobelium | 103 Lr Lawrencium |

Periodic table of the elements showing the elements generally included among the rare earth elements.

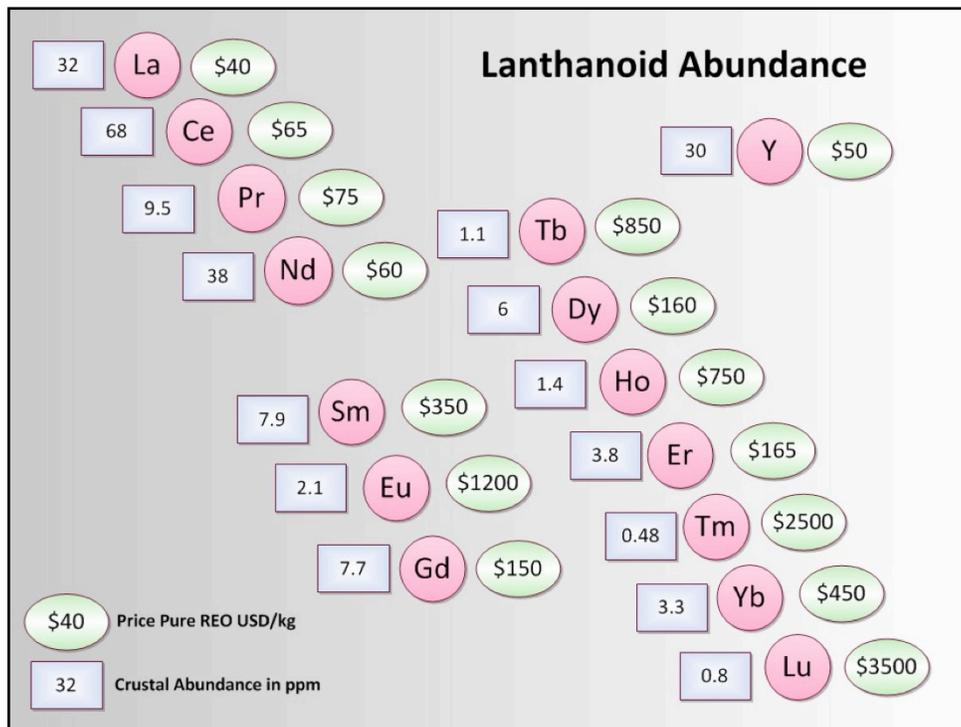
Yellow: The lanthanoid elements. Pm (promethium) is left blank because it does not occur in nature.

Dark Blue: Y (yttrium) is usually included with the lanthanoid elements as a rare earth element because it behaves chemically like a lanthanoid element.

Light blue: Sc (scandium) is sometimes included with yttrium and the lanthanoid elements as a rare earth element, but we do not do so here.



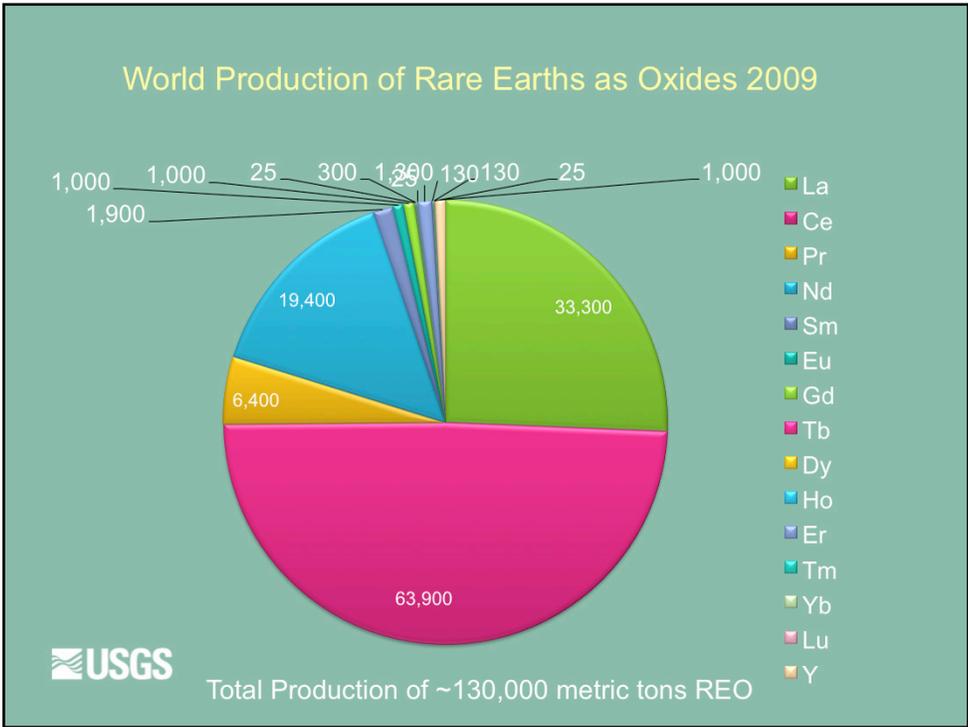
The lanthanoid contraction is a gradual decrease in the ionic radius of each element as atomic number increases. The decrease is approximately 1 Ångstrom per unit atomic number, except when going from Gd (gadolinium) to Tb (terbium) where the decrease is approximately 2 Ångstroms. La (lanthanum) to Gd (gadolinium) are often referred to as the light rare earth elements and Tb (terbium) to Lu (lutetium) as the heavy rare earth elements. Y (yttrium) is included with the heavy rare earth elements because its ionic radius is similar to that of Ho (holmium), one of the heavy rare earth elements. This gradual decrease in ionic radius results in slight differences in solubility between the rare earth elements. The difference is used to separate the individual rare earth elements during the production of rare earth elements chemicals.



Prices are for pure oxides from a leading rare earth elements chemical producer in 2009. Pm (promethium) is not shown because it does not occur in nature and is not commercially available.

REO: rare earth oxide.

USD/kg: United States Dollars per kilogram.



Total estimated global production of the individual rare earth elements as oxides in metric tons for 2009.

Data from Lynas Corp.: www.lynascorp.com.

Principal Use Categories for Rare Earths

| Use Category | Share by Volume % | Share by Value % | Growth Rate % |
|--------------|-------------------|------------------|---------------|
| Catalysts | 22 | 5 | 4 to 7 |
| Magnets | 22 | 37 | 10 to 16 |
| Metal alloys | 20 | 14 | 15 to 20 |
| Polishing | 9 | 4 | 6 to 8 |
| Glass | 9 | 2 | negligible |
| Phosphors | 5 | 31 | 7 to 10 |
| Other | 13 | 7 | 5 to 9 |



Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

CATALYSTS



Automotive Catalysts

6,000 tpy REO

Ce (90%) La (5%) Nd (3%) Pr (2%)

Oxygen storage, carbon removal

Fluid Cracking Catalysts

18,400 tpy REO

La (90%) Ce (10%)

Petroleum refining – cracking heavy molecules

Increases per barrel yield by 7 to 10%



For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

MAGNETS



Rare earth magnets are stronger per unit weight and volume than any other magnet type. Used wherever weight and space are at a premium.



26,500 tpy REO
Nd (69%) Pr (23%)
Dy (5%) Tb (0.2%)
also Sm



 USGS

For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

METAL ALLOYS



NiMH Batteries use La Ni anode to protect against corrosion and increase battery life
La (50%) Ce (33%) Nd (10%) Pr Sm



Prius battery pack has 10-15 kg La

22,500 tpy REO



Mischmetal a La Ce alloy used to purify steel and for special alloys
Ce (52%) La (26%) Nd (17%) Pr (5%)



For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

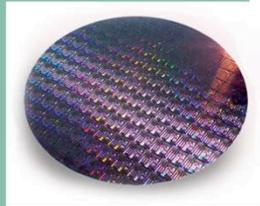
Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

POLISHING



Cerium powders polish glass and silicon better than any other substance. Cerium oxide polishes by chemical reaction rather than abrasion.



15,000 tpy REO
Ce (65%) La (32%) Pr
(3%)



For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

GLASS



Lanthanum makes up as much as 50 percent of glass lenses for digital cameras, including cell phone cameras.



Cerium is added to optical lenses and other specialty glass to inhibit UV transmission.

12,500 tpy REO
Ce (66%) La (24%) Nd (3%)
Pr (1%)



For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

PHOSPHORS



Y, Eu, and Tb phosphors are the RGB phosphors used in all types of light bulbs, display panels, and televisions.



9,000 tpy REO
Y (69%) Ce (11%) La (9%),
Eu (5%) Tb (5%) Gd (2%)



For each application:

- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

OTHER



CERAMIC "DOORKNOB" CAPACITORS

La and Nd are used to stabilize current in ceramic capacitors. Y and Ce are used to stabilize zirconia ceramics, such as those used in solid oxide fuel cells.



7,000 tpy REO
Y (53%) La (17%) Ce (12%) Nd (12%) Pr (6%)



REE-bearing fertilizer is used in China. Rare earths have no known biological function.

8,500 tpy REO – Ce La Y Nd Pr Sm Gd



For each application:

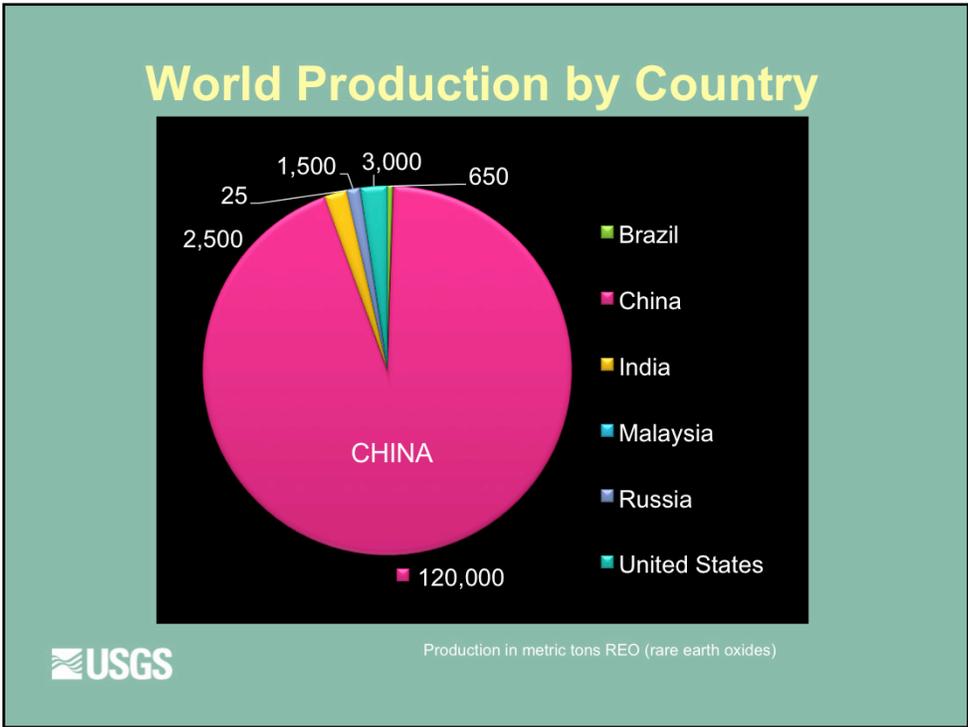
- (1) Global consumption of rare earth oxides (REO) in metric tons per year (tpy) in that particular application;
- (2) The different rare earth elements used in that application along with their percent (%) share of consumption;
- (3) Principal uses in that application area.

Images were found by author on the World Wide Web.

Data from IMCOA (Industrial Minerals Co. of Australia) and Lynas Corp.

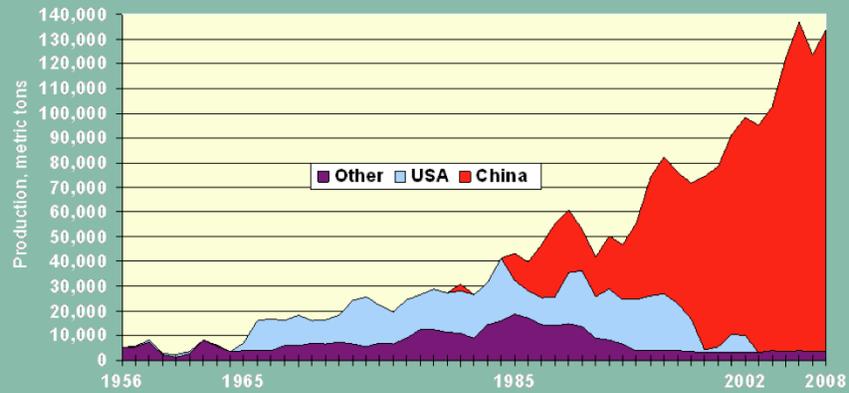
Fertilizer image was found at:

http://www.gxjsf.com/en/products.asp?id=2&menu=ShowDetail&P_Id=1041.



Global production of rare earth elements expressed as total rare earth oxides in metric tons for 2009. Source of data: USGS Mineral Commodity Summaries 2010.

REO Production Trends



Monazite-placer
era

Mountain Pass
era

Chinese era → ?



Sources: USGS Fact Sheet 087-02 updated with recent USGS Minerals Yearbook

Graph courtesy of Daniel Cordier, USGS Mineral Commodity Specialist for rare earth elements.

Types of Rare Earth Deposits

Carbonatite and Peralkaline Intrusive-Related (71,000 tpy REO)

There are very rare intrusive rocks found in rift zones. REE-minerals may be rock-forming minerals or may be deposited by hydrothermal activity in veins.

Heavy Mineral Placers (4,000 tpy REO)

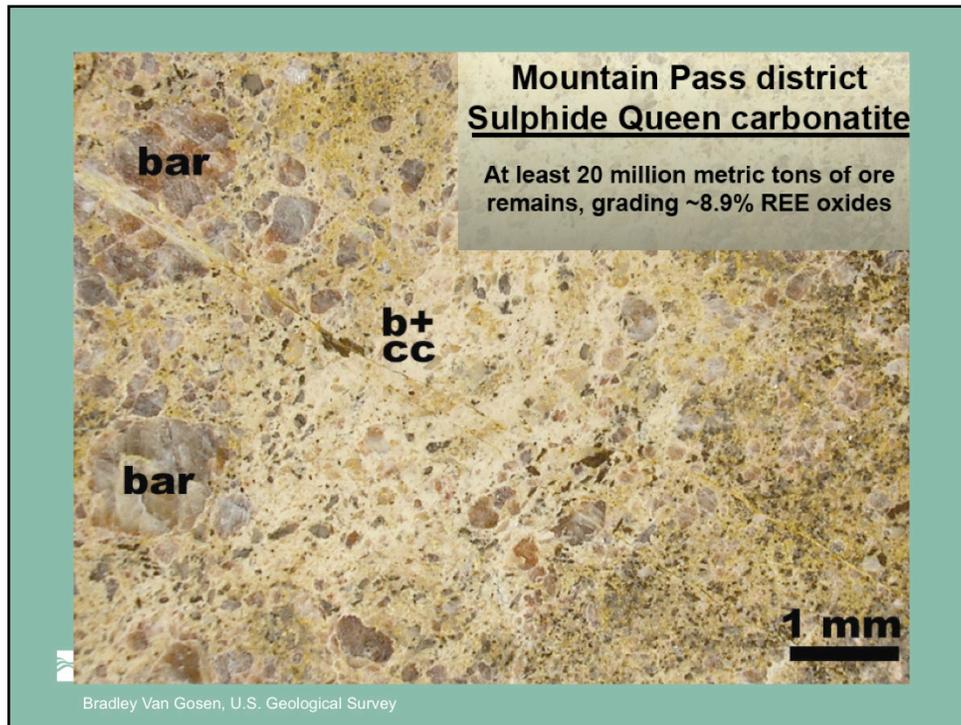
Monazite, a common REE-bearing accessory mineral in igneous, metamorphic, and sedimentary rocks, may be concentrated with other heavy minerals in placer deposits.

Residual (45,000 tpy REO)

Intense weathering of carbonatite and peralkaline intrusives may form concentrated residual deposits or REE minerals. REE-laterite in south China result from weathering of tin granites.



I have allocated global production by deposit types based on my knowledge of the geology of producing rare earth elements (REE) mines. tpy: metric tons per year. REE: rare earth elements. REO: rare earth oxides.



This is a view of the rare earth elements ore at the Mountain Pass mine, California, under a microscope. Scale bar for 1 millimeter is shown in the lower right corner. Labeled minerals are barite (bar) and bastnäsite plus calcite (b+cc). Bastnäsite, a rare earth element carbonate, is the mineral from which rare earth elements are recovered from this mine. Photo courtesy of Bradley Van Gosen, U.S. Geological Survey.



The two black vertical “stripes” with the light-colored “stripe” between comprise the uranium-rare earth elements vein at Bokan Mountain, Alaska. Rock hammer on left for scale. Photo courtesy of Bradley Van Gosen, U.S. Geological Survey.

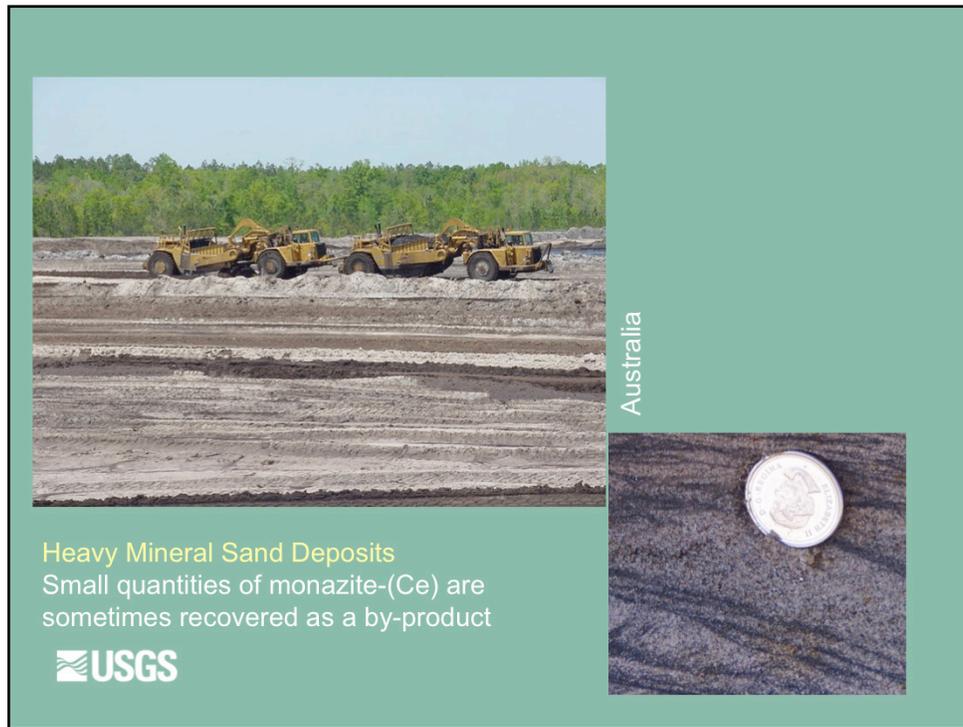


Photo on upper left is of a heavy mineral sands mine in Australia. The photo on the lower right is a close up of the heavy mineral sand with a coin for scale. The principal minerals recovered from these sands are ilmenite and rutile, which are sources of titanium. Monazite, a rare earth elements-bearing mineral, occurs in small quantities in these sands, but is not currently being recovered in Australia. It is recovered from heavy mineral sands in India.

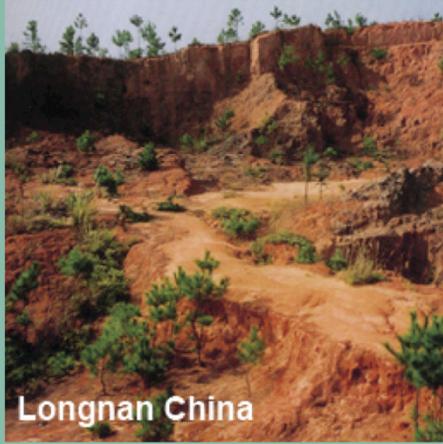
Image on upper left from:

http://project-geo.org/Spring_05/heavy_minerals/.

Image on lower right from:

<http://grandriverironsands.com/index-3.html>.

Ionic Clay Deposits



Longnan China

T. Tagaki, Geological Survey of Japan



About 0.5 percent TREO in a readily leached form in laterite formed on "tin" granites in southern China. Many of these deposits are enriched in HREE.

A significant source of REE, especially HREE, but resources are rapidly being depleted. Mining of these deposits in South China by undercapitalized small operators is environmentally problematic.

TREO: total rare earth oxides.

HREE: heavy rare earths (terbium to lutetium).

REE: rare earth elements.

Photo from Tetsuichi Tagaki, Geological Survey of Japan.

Operating REE Mines



Figure by author.

REE Mine Development Projects

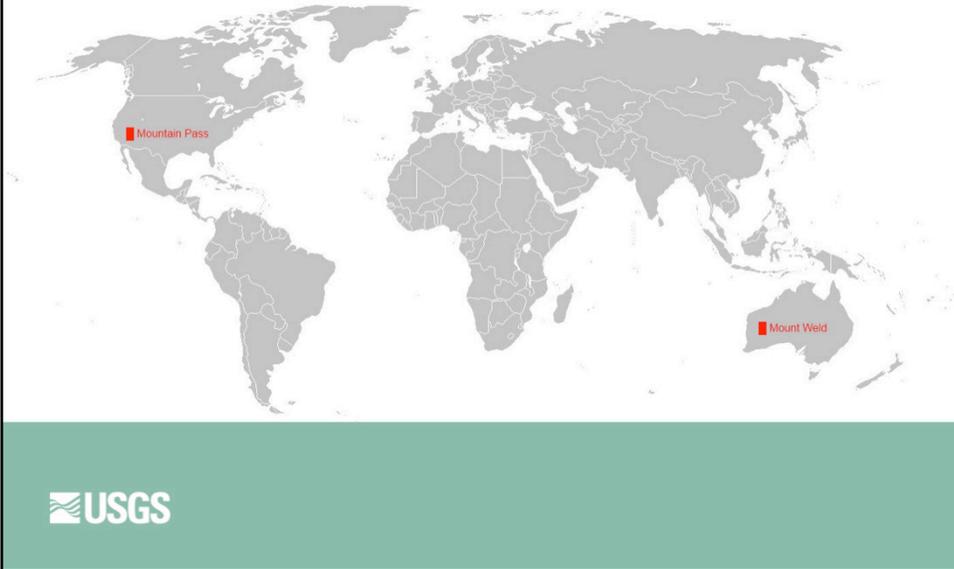


Figure by author.

Advanced REE Mine Projects



Figure by author.

Reserves and Resources

As reported according to SEC, NI 43-101, JORC, or SAMREC standards except for figures in italics

| Country | Reserves metric t TREO | Resources metric t TREO |
|---------------|---------------------------|----------------------------|
| Australia | 1,434,000 | 1,588,000 |
| Brazil | <i>48,000</i> | |
| Canada | | 8,083,000 |
| Greenland | | 875,000 |
| India | <i>3,100,000</i> | |
| Kyrgyzstan | | 49,000 |
| Malawi | | 107,000 |
| Malaysia | <i>30,000</i> | |
| Russia | | <i>1,700,000</i> |
| South Africa | | 977,000 |
| Sweden | | 447,000 |
| United States | 1,009,000 | 589,000 |



China is excluded from these figures because we do not have any reliable data on Chinese reserves and resources for rare earth elements. The resources for Russia are those in various deposits at the Lovozero mining complex. We do not have data for any other rare earth elements deposits in Russia. Reserves for India include the Chavara mine and other heavy mineral sands operations. TREO: total rare earth oxides.

Mining



Mountain Pass, CA

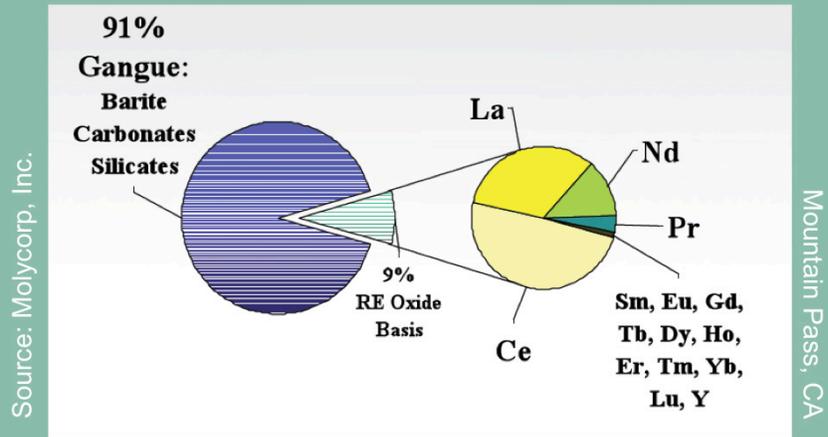
Mining of rare earth deposits is by conventional open pit and underground methods.



Pea Ridge, MO

Photo of Mountain Pass, California, open pit mine from Molycorp, Inc. Photo of headframe on Pea Ridge shaft, Missouri. from Bradley Van Gosen, U.S. Geological Survey.

Mineral Processing

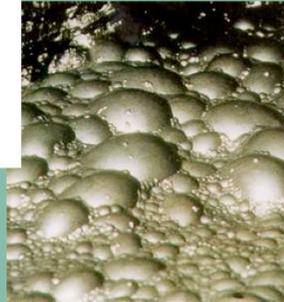
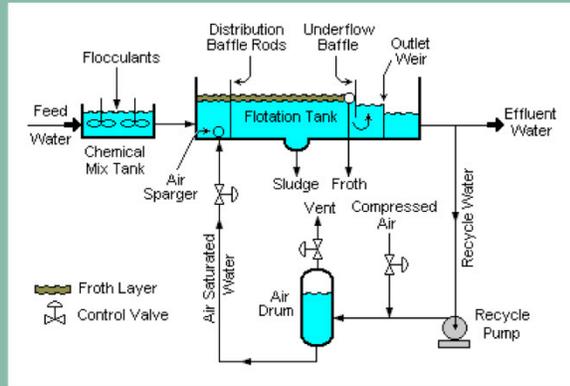


Requires two steps: (1) separate REE minerals from other minerals; (2) separate individual REE.



Graphic from Molycorp, Inc.

Separating Rare Earth Minerals



Froth flotation is the most common method for separation of rare earth minerals from other minerals in ore.

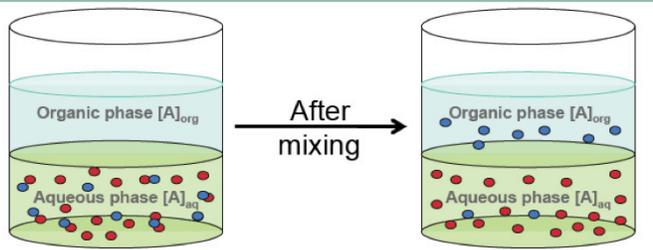


Graphic from : [http://www.thefullwiki.org/Dissolved air flotation](http://www.thefullwiki.org/Dissolved_air_flotation).

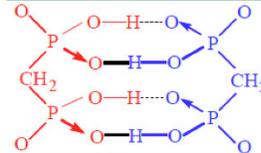
Image from:

http://www3.imperial.ac.uk/newsandeventspggrp/imperialcollege/newssummary/news_23-5-2008-10-37-3?newsid=36894.

Separating Individual REE



Solvent extraction uses small differences in solubility between individual REE. REE minerals are leached with an acid or base, then mixed with an organic chemical that strips a selected REE.



Graphics from John Klaehn and Mark Ogden, Department of Energy, Idaho National Laboratory and John Hryn, Department of Energy, Argonne National Laboratory. Photo of Mountain Pass, California processing plant from Molycorp, Inc.

REE: rare earth elements.

Cost to Produce REO

Reported Operating Costs at Full Production

| Operation | Operating Cost USD/kg TREO | Source |
|---------------|-------------------------------|---------------------|
| Mountain Pass | 2.77 | Molycorp |
| China | 5.58 | Molycorp |
| Mount Weld | 7.00 | Molycorp |
| Nechalacho | 3.70* | Avalon Rare Metals |
| Strange Lake | 0.51** | Quest Rare Minerals |

*Calculated from data reported in preliminary economic assessment.

**Calculated from data reported in a preliminary economic assessment after deducting co-product revenue from costs.



Sources:

Molycorp: A Molycorp, Inc., corporate presentation as of January 2011 accessed June 14, 2011 at :

<http://www.slideshare.net/RareEarthsRareMetals/molycorp-corporate-presentation-jan-2011>.

Avalon Rare Metals: Bakker, F., and others, March 13, 2011, Technical report on the Nechalacho deposit, Thor Lake Project, Northwest Territories, Canada, prepared by Avalon Rare Metals, Inc., NI 43-101 report.

Quest Rare Minerals: Mclaughlin, M., and others, September 24, 2010, Preliminary economic assessment on the Strange Lake B Zone, Quebec, by Wardrop for Quest Rare Minerals, Ltd., NI 43-101 Report.

The USGS cannot verify the accuracy of these operating cost estimates.

Principal Operating Costs

- **Reagents** – Chemicals used to leach REE from concentrates, usually sulfuric or hydrochloric acid
- **Power** – Electrical power required for mineral processing operations
- **Fuel** – Diesel fuel used for blasting and for operating mine equipment
- **Common Element:** Cost of energy



Based on reviews of preliminary economic assessments and feasibility studies for rare earth elements (REE) mining projects.

Cost to Develop a New REO Mine

| Operation | Capital Cost USD millions | Capital Cost USD per metric t REO capacity |
|---------------|------------------------------|--|
| Mount Weld | 566 | 71,000 |
| Nolans Bore* | 499 | 23,000 |
| Nechalacho* | 895 | 45,000 |
| Strange Lake* | 548 | 55,000 |
| Kvanefjeld* | 2,310 | 62,000 |
| Bear Lodge** | 87 | ? |
| Mountain Pass | 681 | 17,000 |

Exchange rates used: AUD:USD 1.0616:1; CAD:USD 1.0286:1.

*Operation with significant co-product production.

**Capital cost for mine and flotation plant only.



Estimated capital costs as reported by the companies that are developing or studying the feasibility of developing these rare earth elements deposits. I have calculated the capital cost per unit capacity using planned output capacities as reported by these firms. USD: United States Dollar. AUD: Australian Dollar. CAD: Canadian Dollar. REO: rare earth oxides.

Time to Develop a New Mine United States

- 14 major metal mines started production in the USA since 2000
- Minimum time from permit application to commercial production was six years
- Maximum time was 23 years
- Average around 10 years
- Excludes pre-permitting exploration, environmental baseline studies, and feasibility studies



Results of research by author as reported in Long, K.R., Van Gosen, B.S., Foley, N.K., and Cordier, D., 2010, The principal rare earth elements deposits of the United States, A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010–5220 . The report can be obtained at: <http://pubs.usgs.gov/sir/2010/5220/>.

Time to Develop a New Mine Elsewhere

- Have not yet done a detailed analysis of lead times for mines in other countries
- Nolans Bore, Australia – Plans to submit its permit application this year and start production later this year with full commercial production by end 2012
- Projects in northern Canada constrained by short exploration seasons and logistical difficulties



See Long, K.R., Van Gosen, B.S., Foley, N.K., and Cordier, D., 2010, The principal rare earth elements deposits of the United States, A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010–5220 for an analysis of the time required to develop a new nickel laterite mine outside of the United States as a situation comparable in complexity to developing a rare earth elements mine outside of the United States. The report can be obtained at: <http://pubs.usgs.gov/sir/2010/5220/>.

Scenario Analysis Future REO Capacity

| Country | Operation | 2011 | 2012 | 2013 | 2014 | 2015-2016 |
|---------------|-----------------|--------|--------|--------|--------|-----------|
| Australia | Dubbo | 0 | 0 | 3,800 | 3,800 | 3,800 |
| | Mount Weld | 11,000 | 22,000 | 22,000 | 22,000 | 22,000 |
| | Nolans Bore | 0 | 20,000 | 20,000 | 20,000 | 20,000 |
| Canada | Nechalacho | 0 | 0 | 0 | 0 | 8,000 |
| | Strange Lake | 0 | 0 | 0 | 0 | 10,000 |
| Greenland | Kvanefjeld | 0 | 0 | 0 | 0 | 37,000 |
| India | Chavara | 2,700 | 2,700 | 2,700 | 2,700 | 2,700 |
| Malaysia | Ipoh | 450 | 450 | 450 | 450 | 450 |
| Russia | Lovozero | 3,000 | 3,000 | 3,000 | 3,000 | 3,000 |
| South Africa | Steenkampskraal | 0 | 0 | 5,000 | 5,000 | 5,000 |
| United States | Bear Lodge | 0 | 0 | 0 | 0 | 10,000 |
| | Mountain Pass | 3,000 | 19,050 | 40,000 | 40,000 | 40,000 |
| Total: | | 20,150 | 67,200 | 96,950 | 96,950 | 161,950 |



An example of a scenario analysis for future rare earth oxides (REO) supplies as completed by the author. Here, the projected supply from sources outside of China is examined. There are many assumptions made to complete this kind of analysis which must be considered when using these figures. If these assumptions prove incorrect, the projected scenarios may not be realized. Figures shown in red have a significant risk of not being realized by the times indicated due to uncertainties in obtaining governmental approvals, financing, construction timeframes, and whether, once built, a mine will perform as planned. Capacity figures (supply) are as reported by the companies that are developing or studying the feasibility of developing the rare earth elements deposits shown.

Scenario Analysis REO Supply

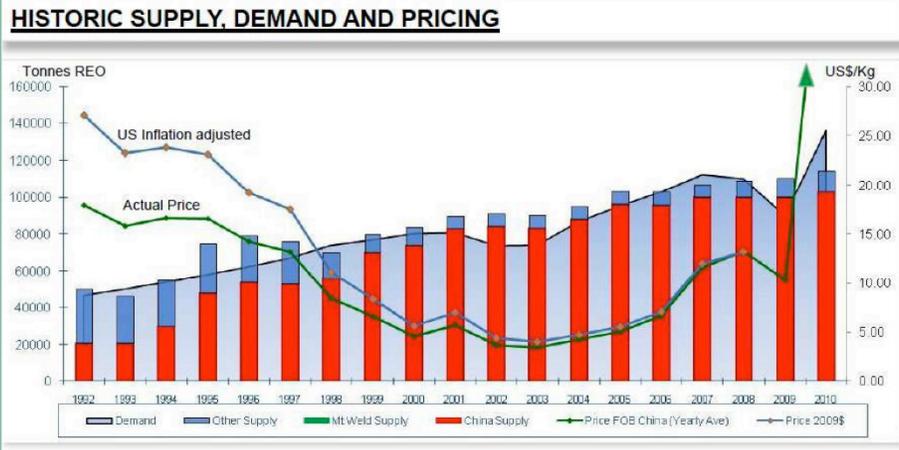
| | 2011 | 2012 | 2013 | 2014 | 2015-2016 |
|------------|---------|---------|---------|---------|-----------|
| Supply | | | | | |
| China | 115,000 | 95,000 | 95,000 | 95,000 | 95,000 |
| ROW Max | 20,000 | 67,000 | 97,000 | 97,000 | 162,000 |
| ROW Min | 9,000 | 47,000 | 68,000 | 68,000 | 68,000 |
| World Max | 135,000 | 162,000 | 192,000 | 192,000 | 257,000 |
| World Min | 124,000 | 142,000 | 163,000 | 163,000 | 163,000 |
| Demand | | | | | |
| Demand Max | 140,000 | 150,000 | 170,000 | 190,000 | 210,000 |
| Demand Min | 130,000 | 130,000 | 150,000 | 170,000 | 190,000 |

Major uncertainties include Chinese production, scheduling of new capacity after 2014, and future demand for REO.



An example of a scenario analysis for future rare earth oxides (REO) supplies as complete by the author. Here, projected global supplies, including those in China, are examined along with global demand. There are many assumptions made to complete this kind of analysis which must be considered when using these figures. If these assumptions prove incorrect, the projected scenarios may not be realized. These particular scenarios suggest a realistic chance of a sufficient surplus in capacity by 2015–2016 to meet projected demand with significant price competition between producers. The most uncertain figures are those for projected demand, which are estimated by IMCOA (Industrial Minerals Co. of Australia). Supply figures (supply) for ROW are as reported by the companies that are developing or studying the feasibility of developing the rare earth elements deposits shown in the previous slide. Data for Chinese supply are based on Chinese production quotas assuming that illegal Chinese production and exports will not be a factor in 2012 and that production quotas will be maintained at the 2012 rate.

Historic REO Price Trends



Source: Lynas Corp



This, or a similar graph is shown in most investor presentations by Lynas Corp. The most recent version (5/2011) can be found at:

http://www.lynascorp.com/content/upload/files/Presentations/Investor_Presentation_May_2011.pdf.

Worst Case Scenario



Ravensthorpe integrated
nickel mine and refinery,
Western Australia
Closed 1/2009 Sold 12/2009
Cost AUD 2 billion – 700
million more than projected
Never achieved commercial
production

The worst case scenario is that either or both Mount Weld or Mountain Pass are unable to achieve commercial production due to technical problems.



The Ravensthorpe story can be found on Wikipedia:

http://en.wikipedia.org/wiki/Ravensthorpe_Nickel_Mine.

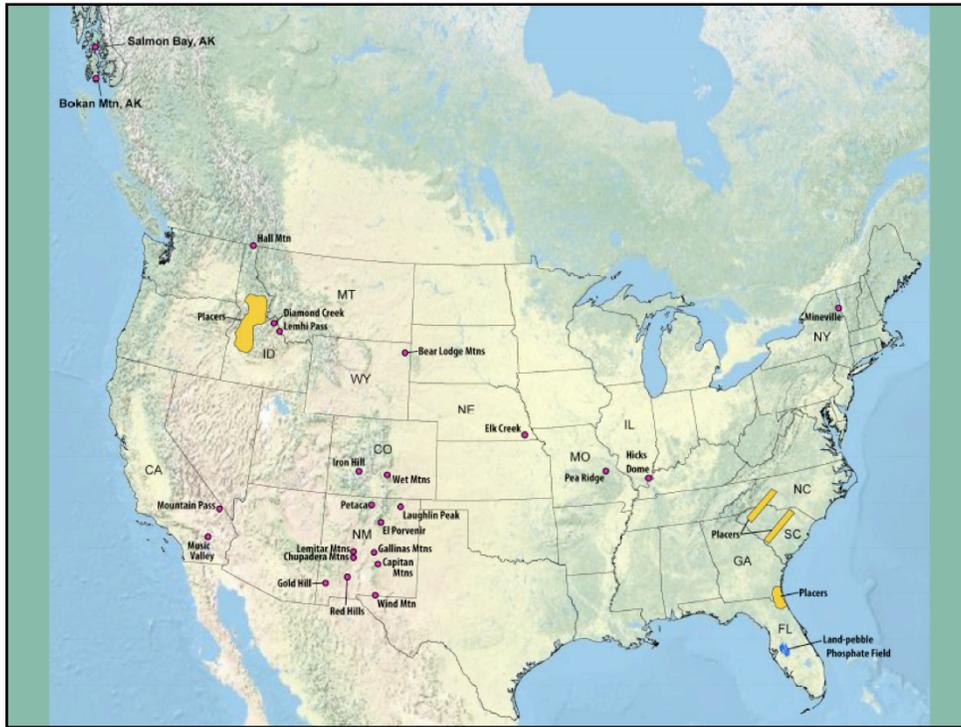
Image is from:

<http://www.watoday.com.au/business/bhp-sells-ravensthorpe-mine-for-376-million-20091209-kio7.html>.

Conclusions

- REE will continue to find increasing use due to their unique properties.
- There is a realistic possibility around 2015–2016 of sufficient REE capacity to meet demand under conditions of healthy price competition.
- REE supplies will be tight and prices high for a few years.
- There is significant downside risk that newly developed mines will not perform as planned.





Location of principal rare earth elements deposits in the United States. See Long, K.R., Van Gosen, B.S., Foley, N.K., and Cordier, D., 2010, The principal rare earth elements deposits of the United States, A summary of domestic deposits and a global perspective: U.S. Geological Survey Scientific Investigations Report 2010–5220 for more information on these deposits and associated resources. The report can be obtained at:

<http://pubs.usgs.gov/sir/2010/5220/>.

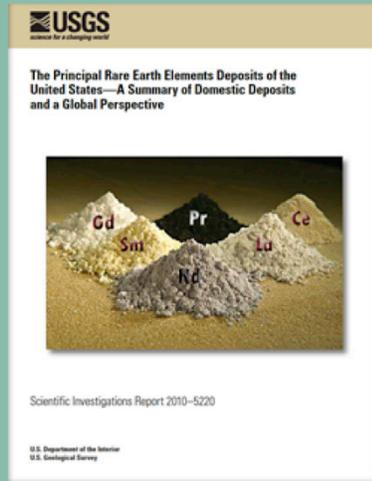
USGS REE Resources & Activities

- **NMIC REE Page** http://minerals.usgs.gov/minerals/pubs/commodity/rare_earths/
- **NMIC REE Specialist**
Dan Cordier dcordier@usgs.gov
(703) 648-7723
- **Minerals at Risk and For Emerging Technologies Project** (ends this year)
- **Future Project?**



Basic sources of information on rare earth elements (REE) at the U.S. Geological Survey.

USGS REE Publications



The Principal Rare Earth Elements
Deposits of the United States

<http://pubs.usgs.gov/sir/2010/5220/>



This recent USGS publication reviews the geology and resource status of domestic rare earth elements (REE) deposits in a global context.