Government Documents on Rare Earth Minerals

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October 16, 2012

What Are Rare Earth Minerals?

- Lithium, Gallium, Rhenium, Tantalum, Niobium, Neodymium, Nickel, Cobalt, etc.
- Used in multifaceted technologies and accessories with civilian and military applications including:
- Automotive converters
- Clean Energy Industry Applications e.g. wind turbines
- Computer Monitors
- Opto-Electronic Devices (esp. in aerospace)

What Are Rare Earth Minerals: Characteristics

- Semi-Conductor Chips, Satellites
- F-22 Raptor & F-35 Joint Strike Fighter aircraft
- Portable phones, smart phones
- Lasers, Heat-Resistant, Wear-Resistant
- Medicinal Uses, High Strength Ceramics
- Unmanned Aerial Vehicles

Why Should I Care?

- Most rare earth minerals are only available from foreign suppliers e.g:
- China (Most prominent supplier-controls 90% of global supplies)
- Afghanistan, Australia, Brazil, Bolivia, Canada, Chile, Congo possess rare earths, some U.S. holdings
- Volatile markets and political turmoil in producing countries can lead to unstable prices

Why Should I Care?

- Oct. 21, 2010-Japanese seizure of Chinese fishing boat trespassing in East China Sea causes Beijing to embargo rare earth mineral shipments to Tokyo for several weeks.
- U.S. and other consuming countries highly dependent on these resources in civilian and military sectors.
- U.S. and other countries need to enhance domestic rare earth supplies to avoid economic disruption and inability to meet civilian and defense market needs.
- Developing these resources becomes more difficult during current fiscally constrained environment.
- Military conflict over access to these resources is possible.
- Government intervention can affect supplies via taxes, subsidies, quotas, trade measures, regulations, and R&D support.

U.S. Government Documents on Rare Earths

Produced by numerous agencies including USGS, DOE, DOD, Congress, and congressional support agencies

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Minerals Yearbook

The Minerals Yearbook is an annual publication that reviews the mineral and material industries of the United States and foreign countries. The Yearbook contains statistical data on materials and minerals and includes information on economic and technical trends and development. The Minerals Yearbook includes chapters on approximately 90 commodities and over 175 countries.

- **Volume I. -- Metals and Minerals**

  This volume, covering metals and minerals, contains chapters on approximately 90 commodities. In addition, this volume has chapters on mining and quarrying trends and on statistical surveying methods used by Minerals Information, plus a statistical summary.

- **Volume II. -- Area Reports: Domestic**

  This volume reviews the U.S. mineral industry by State and Island possessions. It presents salient statistics on production, consumption, and other pertinent data for each State and is prepared in cooperation with State Geological Surveys or related agencies.

- **Volume III. -- Area Reports: International**

  This volume of the Minerals Yearbook provides an annual review of mineral production and trade and of mineral-related government and industry developments in more than 175 foreign countries. Each report includes sections on government policies and programs, environmental issues, trade and production data, industry structure and ownership, commodity sector developments, infrastructure, and a summary outlook.

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Rare Earths

By Daniel J. Cordier

Domestic survey data and tables were prepared by Maria Arguelles, statistical assistant; the world production tables were prepared by Glenn J. Wallace, international data coordinator; and the map figure was designed by Robert M. Callaghan, geographic information specialist.

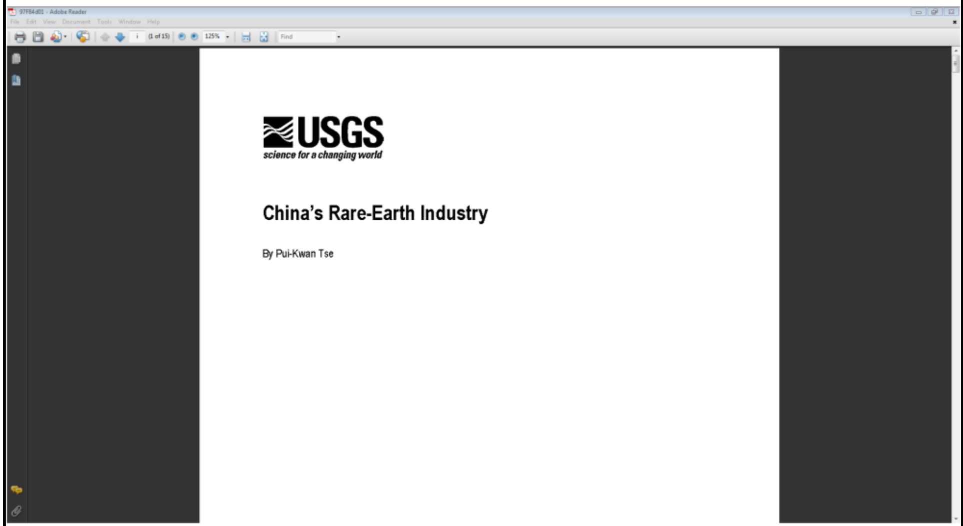
In 2009, world rare-earth production was primarily from the mineral bastnäsite. Rare earths were not mined in the United States in 2009. Rare-earth ores were primarily mined by China, with smaller amounts mined in India, Brazil, and Malaysia, listed in order of decreasing production. Throughout 2009, processing of intermediate rare-earth concentrates took place at the Mountain Pass Mine in California.

Domestic use of scandium decreased in 2009 and overall consumption remained small. Demand was primarily for aluminum alloys used in baseball and softball bats. Scandium alloys, compounds, and metals were used in analytical standards, metallurgical research, and sports equipment. Minor amounts of high-purity scandium were used in semiconductors and specialty lighting.

Based on import data from the Port Import Export Reporting Service (PIERS) database of Commonwealth Business Media, Inc. (undated), domestic yttrium consumption decreased by 8.8% in 2009 compared with that of 2008. Yttrium was used primarily in fluorescent lamp and cathode-ray tube (CRT) phosphors; lesser amounts were used in structural ceramics and oxygen sensors.

The rare earths are a moderately abundant group of 17 elements comprising the 15 lanthanoids, scandium, and yttrium. The division is based on the lanthanoid LREE having unpaired electrons in the 4f electron shell and HREE having paired electrons in the 4f electron shell. Gadolinium has a very stable one-half filled 4f electron shell with seven unpaired electrons. Proceeding with terbium and continuing along the series through lutetium, paired electrons are progressively added to the 4f electron shell for each respective element in the HREE lanthanoid series until there is a full complement of 14 electrons in the 4f electron shell of lutetium. The division between LREE and HREE lanthanoids falls between gadolinium and terbium. Yttrium is included as a HREE even though it is not part of the lanthanoid contraction series.

Scandium (atomic number 21), a transition metal, is the lightest REE but it is not classified as one of the group of LREE nor one of the HREE. It is the 31st most abundant element in the Earth's crust, with an average crustal abundance of 22 ppm. Scandium is a soft, lightweight, silvery-white metal, similar in appearance and weight to aluminum. It is represented by the chemical symbol Sc and has one naturally occurring isotope. Although its occurrence in crustal rocks is greater than that of lead, mercury, and the precious metals, scandium rarely occurs in concentrated quantities because it does not selectively combine with the common ore-forming anions.



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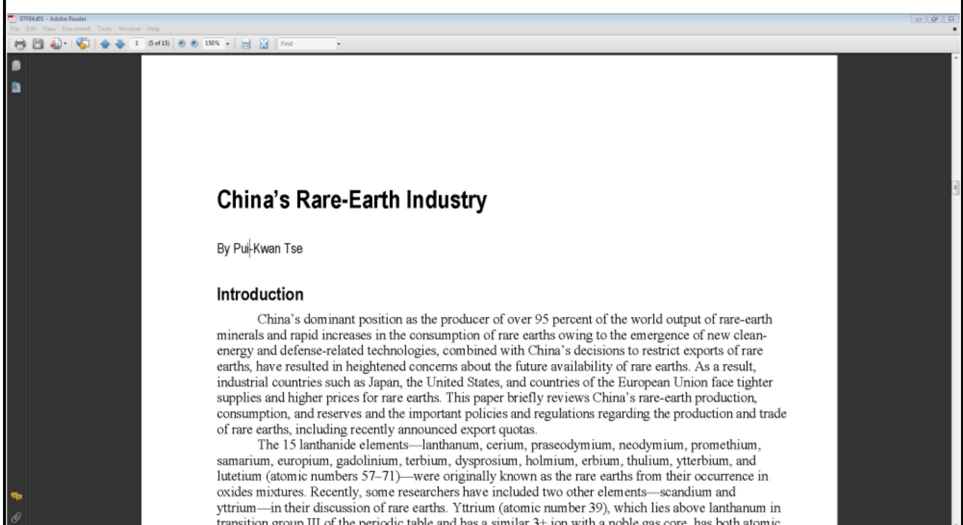
China's Rare-Earth Industry

By Pui-Kwan Tse



China's Rare-Earth Industry

By Pui-Kwan Tse

Introduction

China's dominant position as the producer of over 95 percent of the world output of rare-earth minerals and rapid increases in the consumption of rare earths owing to the emergence of new clean-energy and defense-related technologies, combined with China's decisions to restrict exports of rare earths, have resulted in heightened concerns about the future availability of rare earths. As a result, industrial countries such as Japan, the United States, and countries of the European Union face tighter supplies and higher prices for rare earths. This paper briefly reviews China's rare-earth production, consumption, and reserves and the important policies and regulations regarding the production and trade of rare earths, including recently announced export quotas.

The 15 lanthanide elements—lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, and lutetium (atomic numbers 57–71)—were originally known as the rare earths from their occurrence in oxides mixtures. Recently, some researchers have included two other elements—scandium and yttrium—in their discussion of rare earths. Yttrium (atomic number 39), which lies above lanthanum in transition group III of the periodic table and has a similar 3+ ion with a noble gas core, has both atomic

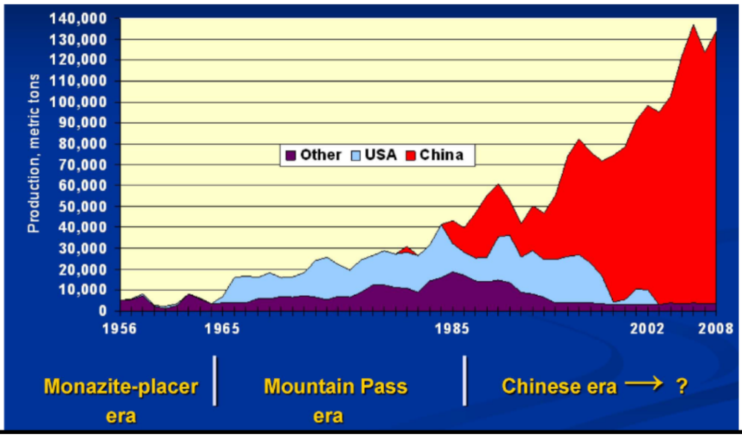
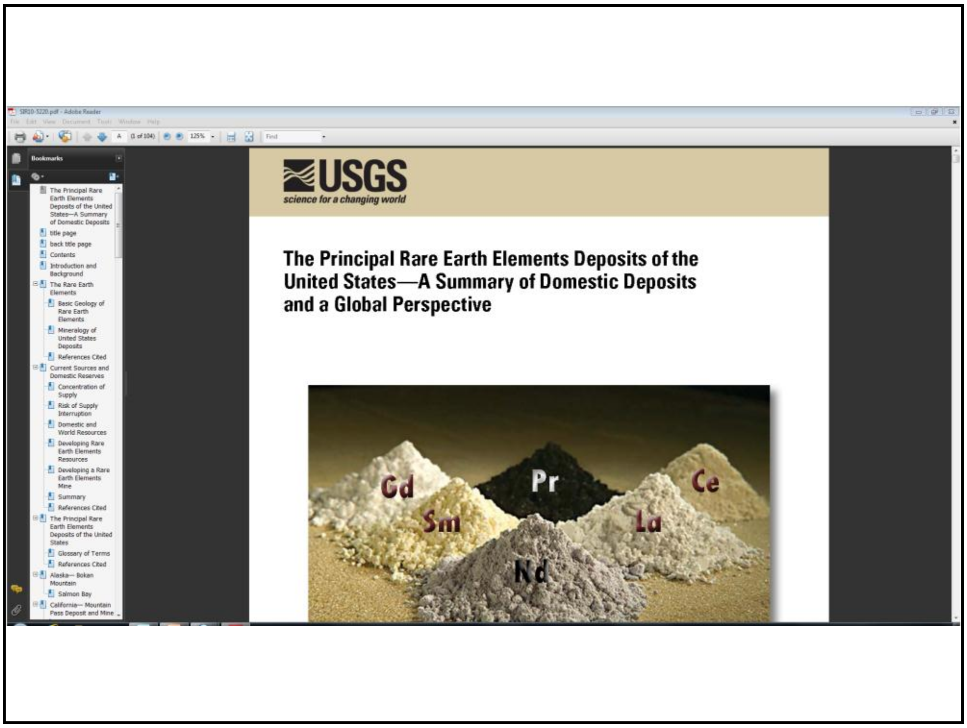


Table 2. China's rare-earth export duty rates.

[In percentage. Abbreviation used: NA, not available. Sources: China Customs Import and Export Tariff Department (2007–2011)]

Commodity	Export duty rate (%)				
	2007	2008	2009	2010	2011
Yttrium oxide	10	25	25	25	25
Lanthanum oxide	10	15	15	15	15
Cerium oxide, hydroxide, carbonate, and others	10	15	15	15	15
Praseodymium	NA	NA	NA	NA	NA
Neodymium oxide	10	15	15	15	15
Europium and its oxide	10	25	25	25	25
Gadolinium	NA	NA	NA	NA	NA
Terbium and its oxide, chloride, and carbonate	10	25	25	25	25
Dysprosium oxide, chloride, and carbonate	10	25	25	25	25
Holmium	NA	NA	NA	NA	NA
Erbium	NA	NA	NA	NA	NA
Thulium	NA	NA	NA	NA	NA
Ytterbium	NA	NA	NA	NA	NA
Lutetium	NA	NA	NA	NA	NA
Other rare-earth oxide	10	15	15	15	15
Mixed rare-earth chlorides and fluorides	10	15	15	15	15
Mixed rare-earth carbonates	10	15	15	15	15
Mixed rare-earth, yttrium, and scandium compounds and metals (including battery grade)	10	25	25	25	25
Non-mixed rare-earth carbonates	10	15	15	15	15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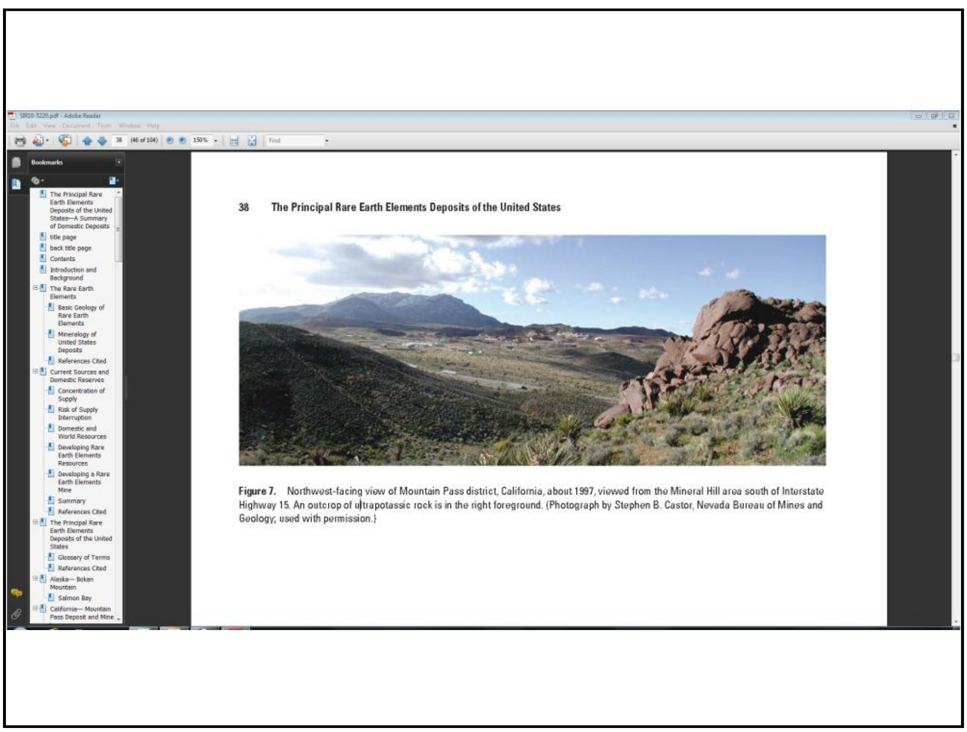
The Principal Rare Earth Elements Deposits of the United States—A Summary of Domestic Deposits and a Global Perspective
Gd
Sm
Pr
Nd
La
Ce


38 The Principal Rare Earth Elements Deposits of the United States
Figure 7. Northwest-facing view of Mountain Pass district, California, about 1997, viewed from the Mineral Hill area south of Interstate Highway 15. An outcrop of ultrapotassic rock is in the right foreground. (Photograph by Stephen B. Castor, Nevada Bureau of Mines and Geology; used with permission.)

Missouri—Pea Ridge Iron Deposit and Mine

Location: The Pea Ridge iron orebody and mine site is located in Washington County, Missouri, about 97 km (60 mi) southwest of St. Louis. Latitude: 38.12621 N., Longitude: 91.04766 W.; datum: WGS84

Deposit type and basic geology: Rare earth elements (REE)–bearing breccia pipes cut through the Pea Ridge massive magnetite-iron orebody. The Pea Ridge deposit is hosted by Precambrian volcanic rocks of the St. Francois terrane of southeastern Missouri. The magnetite-rich orebody is interpreted as a high-temperature, magmatic-hydrothermal deposit (Sidder and others, 1993) in ash-flow tuffs and lavas, which may have formed in the root of a volcanic caldera (Nuelle and others, 1991). Four mapped REE-bearing breccia pipes steeply crosscut the magnetite-hematite orebody and its altered rhyolite host rock. Exposed portions of the breccia pipes are as much as 60 m (197 ft) in horizontal length and as much as 15 m (49 ft) in width; the pipes extend below the mined levels to an undetermined depth (Seeger and others, 2001). Rare earth elements–bearing minerals in the breccia pipes include monazite, xenotime, and minor bastnasite and britholite. The REE concentrations reported in the breccia pipes are consistently high but variable. Nuelle and others (1992, p. A1) state, "Total REE oxide content of samples of the groundmass material, which are not diluted with lithic fragments, average about 20 weight percent." Seeger and others (2001, p. 2) state, "Total REE oxide concentrations of grab samples range from about 2.5 to 19 weight percent." Bulk sampling by the

Estimated resources: A U.S. Bureau of Mines report by Whitten and Yancey (1990) estimated that the breccia pipes contain about 600,000 metric tons (660,000 tons) of REE reserves with an average grade of 12 percent REE oxides. The report does not indicate the data used to calculate this estimate. However, a similar value of 600,000 short tons is mentioned as a note on another internal company memo (provided by Jim Kennedy, electronic communication, October 2008); that memo is dated 10-25-89 and signed by Larry J. Tucker (retired Pea Ridge mine superintendent); supporting calculations for this value are missing. A copy of another internal company memo (provided by Jim Kennedy, electronic communication, October 2008 and dated 11-22-88 and signed by Larry J. Tucker) indicates that there is a combined, probable reserve in two of the breccia pipes of approximately 250,000 metric tons (276,000 tons) of mineralized rock, grading about 13 percent REE (note: weight percent, not oxide equivalent). The surface tailings contain additional lanthanide resources primarily in fine-grained, REE-bearing minerals, chiefly monazite and xenotime, that form inclusions within apatite. The apatite also contains minor amounts of REE in its structure; apatite is found in variable concentrations throughout the iron orebody (Vierrether and Cornell, 1993).

Detailed Discussion

Rare earth elements (REE)–bearing breccia pipes cut through the Pea Ridge massive magnetite iron-orebody in Washington County, Missouri, about 97 km (60 mi) southwest of St. Louis. The iron deposit as a whole contains concentrations of REE that may be economically recoverable as a primary product or as a byproduct of iron ore production

THE MINERAL INDUSTRY OF AFGHANISTAN

By Chin S. Kuo

Afghanistan has large untapped energy and mineral resources, which have great potential to contribute to the country's economic development and growth. The major mineral resources include chromium, copper, gold, iron ore, lead and zinc, lithium, marble, precious and semiprecious stones, sulfur, and talc. The energy resources consist of natural gas and petroleum. The Government was working to introduce new mineral and hydrocarbon laws that would meet international standards of governance.

The U.S. Geological Survey (USGS) and the British Geological Survey were doing resource estimation work in the country. Prior to that work, Afghanistan's exploration activity had been conducted by geologists from the Soviet Union who left good-quality geologic records that indicate significant mineral potential. Resource development would require improvements in the infrastructure and security in Afghanistan. The Government had awarded contracts to develop the Aynak copper project and the Hajigak iron ore project; in addition, the Government could offer tenders for new exploration, including exploration of copper at Balkhab, gold at Badakhshan, gemstones and lithium at Nuristan, and oil and gas at Sheberghan.

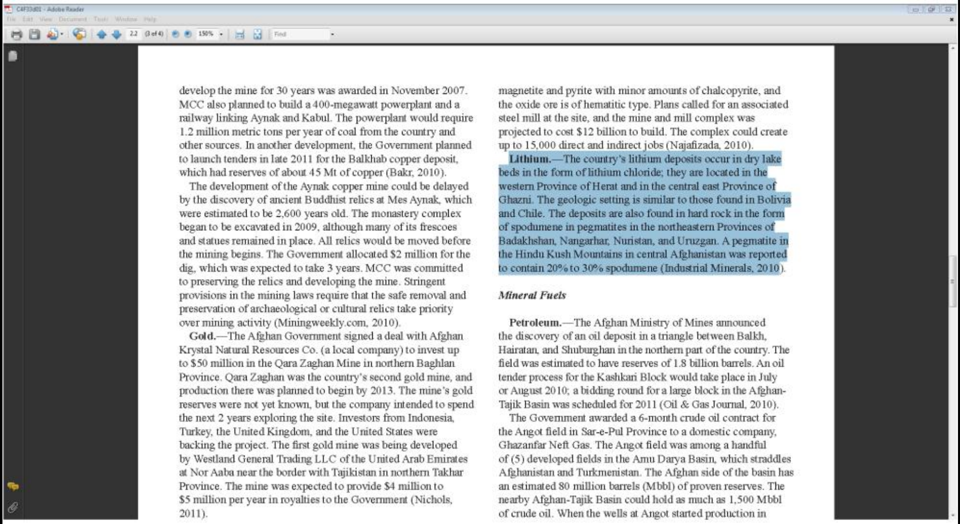
The Ministry of Mines drew up its first business reform plan in a bid to create a more accountable and transparent mining industry. Afghanistan joined the Extractive Industries Transparency Initiative as a candidate country. It was expected to allow Afghan exporters to transport minerals and other goods into Europe. Metallurgical Group Corp. of China (MCC) also planned to build a railroad to transport copper ore in Afghanistan from Aynak to Kabul (Farmer, 2010).

Production

Owing to the lack of mineral production data reported by the miners, information about Afghanistan's mining activities was not readily available, but they appeared to be limited in scope. The Government provided only partial output data for 2010 (table 1). Production of barite was estimated by the USGS to be about 2,000 metric tons (t); chromite, 6,000 t; and natural gas liquids, 45,000 barrels. In the process of reconstruction and infrastructure development, output of construction minerals was estimated to have increased to meet the domestic requirements. Production of cement increased by 13% compared with that of 2009.

Structure of the Mineral Industry

Privatization of Afghanistan's state-owned companies, which controlled many of the country's mineral resources, was ongoing but not complete. Investment in the mining sector by private domestic companies and foreign investors was encouraged by the Government, which had offered the first contract for development of the Aynak copper project to two Chinese



develop the mine for 30 years was awarded in November 2007. MCC also planned to build a 400-megawatt powerplant and a railway linking Aynak and Kabul. The powerplant would require 1.2 million metric tons per year of coal from the country and other sources. In another development, the Government planned to launch tenders in late 2011 for the Balkhab copper deposit, which had reserves of about 45 Mt of copper (Bakr, 2010).

The development of the Aynak copper mine could be delayed by the discovery of ancient Buddhist relics at Mes Aynak, which were estimated to be 2,600 years old. The monastery complex began to be excavated in 2009, although many of its frescoes and statues remained in place. All relics would be moved before the mining begins. The Government allocated $2 million for the dig, which was expected to take 3 years. MCC was committed to preserving the relics and developing the mine. Stringent provisions in the mining laws require that the safe removal and preservation of archaeological or cultural relics take priority over mining activity (Miningweekly.com, 2010).

Gold.—The Afghan Government signed a deal with Afghan Krystal Natural Resources Co. (a local company) to invest up to $50 million in the Qara Zaghan Mine in northern Baghlan Province. Qara Zaghan was the country's second gold mine, and production there was planned to begin by 2013. The mine's gold reserves were not yet known, but the company intended to spend the next 2 years exploring the site. Investors from Indonesia, Turkey, the United Kingdom, and the United States were backing the project. The first gold mine was being developed by Westland General Trading LLC of the United Arab Emirates at Nor Aaba near the border with Tajikistan in northern Takhar Province. The mine was expected to provide $4 million to $5 million per year in royalties to the Government (Nichols, 2011).

magnetite and pyrite with minor amounts of chalcopyrite, and the oxide ore is of hematitic type. Plans called for an associated steel mill at the site, and the mine and mill complex was projected to cost $12 billion to build. The complex could create up to 15,000 direct and indirect jobs (Najafizada, 2010).

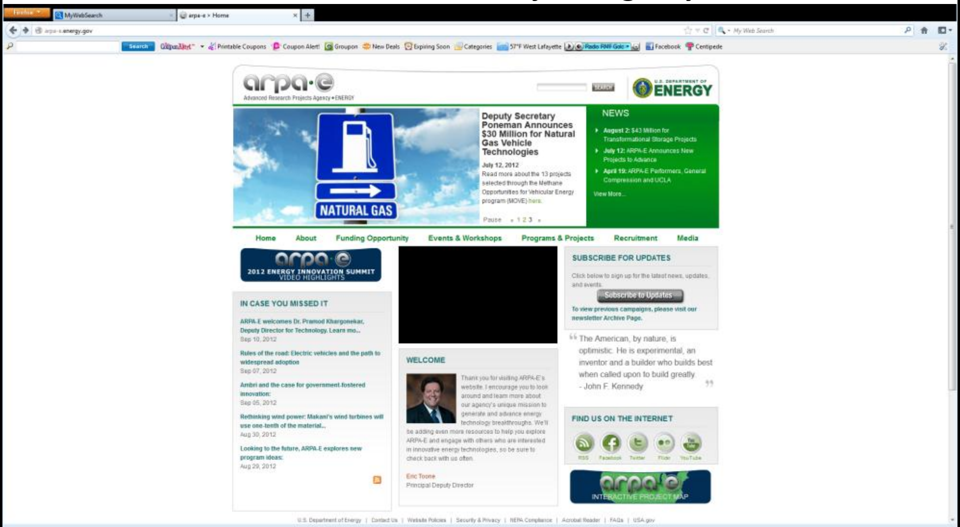
Lithium.—The country's lithium deposits occur in dry lake beds in the form of lithium chloride; they are located in the western Province of Herat and in the central east Province of Ghazni. The geologic setting is similar to those found in Bolivia and Chile. The deposits are also found in hard rock in the form of spodumene in pegmatites in the northeastern Provinces of Badakhshan, Nangarhar, Nuristan, and Uruzgan. A pegmatite in the Hindu Kush Mountains in central Afghanistan was reported to contain 20% to 30% spodumene (Industrial Minerals, 2010).

Mineral Fuels

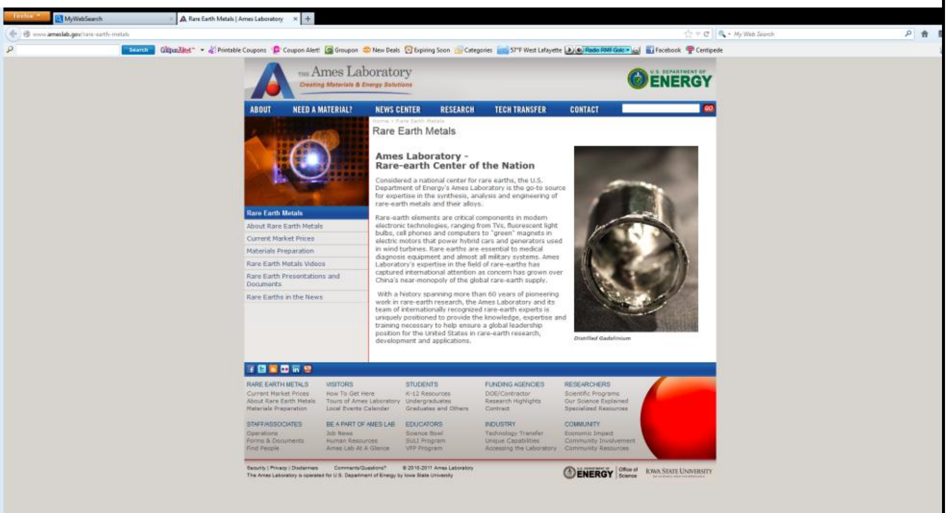
Petroleum.—The Afghan Ministry of Mines announced the discovery of an oil deposit in a triangle between Balkh, Hairatan, and Shuburghan in the northern part of the country. The field was estimated to have reserves of 1.8 billion barrels. An oil tender process for the Kashkari Block would take place in July or August 2010; a bidding round for a large block in the Afghan-Tajik Basin was scheduled for 2011 (Oil & Gas Journal, 2010).

The Government awarded a 6-month crude oil contract for the Angot field in Sar-e-Pul Province to a domestic company, Ghazanfar Neft Gas. The Angot field was among a handful of (5) developed fields in the Amu Darya Basin, which straddles Afghanistan and Turkmenistan. The Afghan side of the basin has an estimated 80 million barrels (Mbbl) of proven reserves. The nearby Afghan-Tajik Basin could hold as much as 1,500 Mbbl of crude oil. When the wells at Angot started production in

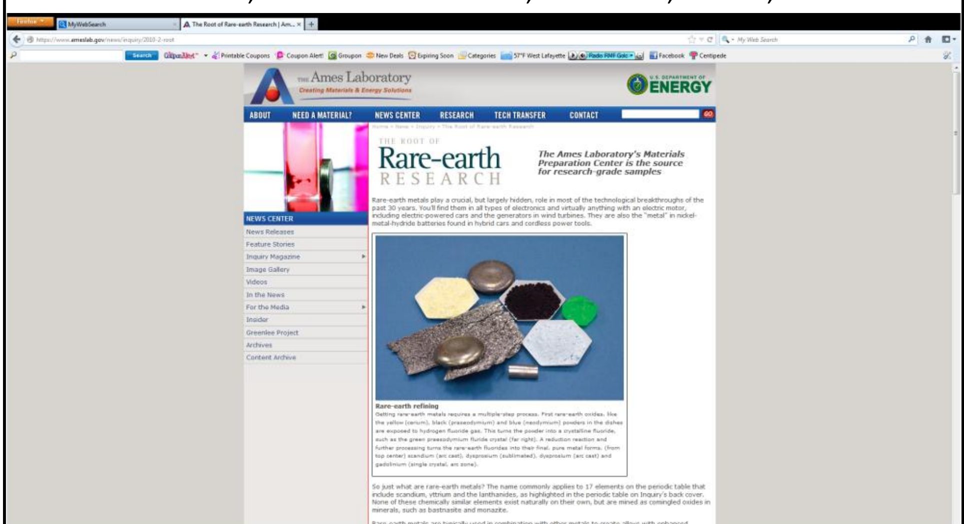
DOE Advanced Research Projects Agency ARPA-E



DOE Ames Laboratory Rare Earths Website



Other universities receiving ARPA-E rare earth grant funding include Alabama, Case Western Reserve, Penn State, Purdue, etc.



THE RARE EARTH CRISIS – THE LACK OF AN INTELLECTUAL INFRASTRUCTURE

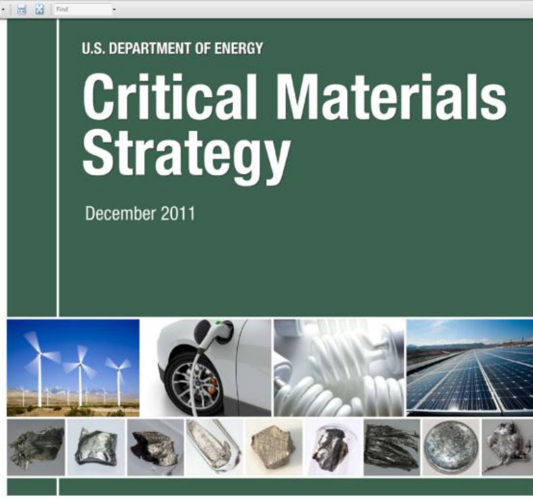
Karl A. Gschneidner, Jr., Ames Laboratory, Iowa State University, Ames, IA 50011-3020

Background

The rare earth crisis slowly evolved over a ten to fifteen year period beginning in the mid-1980s, when the Chinese began to export mixed rare earth concentrates. With time, they moved up the supply chain and began to export the individual rare earth oxides and metals in the early 1990s. By the late 1990s the Chinese exported higher value products, such as magnets, phosphors, polishing compounds, catalysts, and in the 21st Century they supplied finished products including electric motors, computers, batteries, liquid crystal displays, TVs and monitors, mobile phones, i-pods, compact fluorescent lamp (CFL) light bulbs, etc. As they moved to higher value products, the Chinese slowly drove the various US industrial producers and commercial enterprises in the USA, Europe, Japan, etc. out of business by manipulating the rare earth commodity prices. Because of this, the technically trained engineers and scientists working on rare earths containing products from mining, to separations, to processing, to primary rare earth chemical and metallurgical production, to manufacturing semi-finished and final products were laid-off and moved to other fields or retired.

Considering all of the above, today there is a serious lack of technically trained personnel with the appropriate expertise and experience to bring the entire rare earth industry from mining to original equipment manufacturers (OEM) up to full speed in the next few years. Accompanying this disappearance of technical expertise, innovation and new products utilizing rare earth elements has slowed dramatically, and it may take a decade or more to recapture

DOE Critical Materials Strategy



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Executive Summary

This report examines the role of rare earth metals and other materials in the clean energy economy. It is an update of the 2010 *Critical Materials Strategy*, which highlighted the importance of certain materials to wind turbines, electric vehicles (EVs), photovoltaic (PV) thin films and energy-efficient lighting. The 2011 *Critical Materials Strategy* includes updated criticality assessments, market analyses and technology analyses to address critical materials challenges. It was prepared by the U.S. Department of Energy (DOE) based on data collected and research performed during 2011.

The report's highlights include:

- Several clean energy technologies—including wind turbines, EVs, PV thin films and fluorescent lighting—use materials at risk of supply disruptions in the short term. Those risks will generally decrease in the medium and long terms.
- Supply challenges for five rare earth metals (dysprosium, neodymium, terbium, europium and yttrium) may affect clean energy technology deployment in the years ahead.
- In the past year, DOE and other stakeholders have scaled up work to address these challenges. This includes new funding for priority research, development of DOE's first critical materials research plan, international workshops bringing together leading experts and substantial new coordination among federal agencies working on these topics.
- Building workforce capabilities through education and training will help address vulnerabilities and realize opportunities related to critical materials.
- Much more work is required in the years ahead.

This report focuses on several clean energy technologies expected to experience high growth in coming years. The scenarios presented are not predictions of the future. Future supply and demand for materials may differ from these scenarios due to breakthrough technologies, market response to

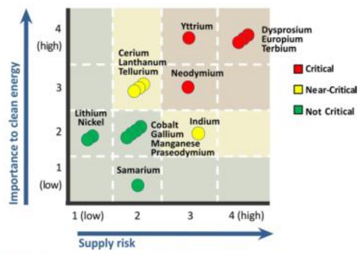
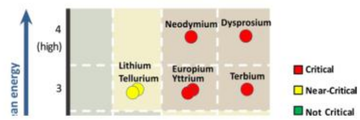


Figure ES-1. Short-Term (Present–2015) Criticality Matrix



The materials were selected for study based on factors contributing to the risk of supply disruption, including a small global market, lack of supply diversity, market complexities caused by coproduction and geopolitical risks.

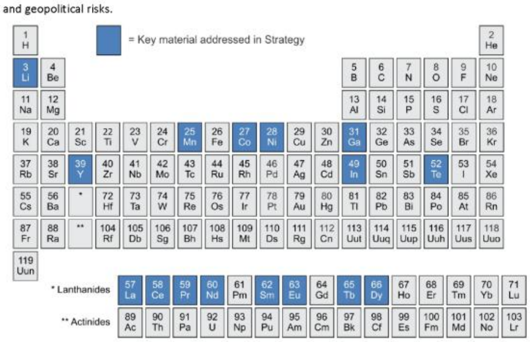


Figure 1-1. Key Materials within the Periodic Table of the Elements

While these materials are generally used in low volumes relative to other resources, the anticipated deployment of clean energy technologies could substantially increase worldwide demand. In some cases, clean energy technology demand could compete with a rising demand for these materials from other technology sectors. In some cases, these key materials have production that is currently

Chapter 2. Use of Key Materials in Clean Energy Technologies

2.1 Introduction

This chapter focuses on three special topics:

- **Fluid Cracking Catalysts in Oil Refining**
- **Technology Transitions in High-Efficiency Lighting**
- **Permanent Magnets in Wind Turbines and Electric Vehicles**

These topics were selected because of interest expressed by stakeholders following the release of the U.S. Department of Energy's (DOE's) 2010 *Critical Materials Strategy*.

In addition, this chapter briefly explores the use of rare earths and other materials in nine technologies: photovoltaic (PV) films, vehicle batteries, electric bicycles, grid storage batteries, magnetic refrigeration, automatic catalytic converters, gas turbine blades, fuel cells and vehicle lightweighting. Table 2-1 provides an overview of the key materials used in leading clean energy technologies. [2]

Table 2-1. Materials in Clean Energy Technologies and Components

	Photovoltaic Films	Wind Turbines	Vehicles		Lighting
MATERIAL	*Coatings*	*Magnets*	*Magnets*	*Batteries*	*Phosphors*
Indium	●				
Gallium	●				
Tellurium	●				
Dysprosium		●	●		
Praesodymium		●	●	●	
Neodymium		●	●	●	
Lanthanum				●	●

Table 3-3. Market Capitalization of Select Rare Earth Companies (as of October 13, 2011)

Company (Country)	Market Capitalization ($ Million USD)	Primary Mines
Molycorp, Inc. (United States)	3,080	Mountain Pass
Lynas Corporation, Ltd. (Australia)	2,222	Mount Weld
Avalon Rare Metals, Inc. (Canada)	389	Nechalacho (Thor Lake)
Alkane Resources, Ltd. (Australia)	340	Dubbo
Arafura Resources, Ltd. (Australia)	250	Nolans Bore
Rare Element Resources, Ltd. (United States)	243	Bear Lodge (Bull Hill Zone)
Great Western Minerals Group, Ltd. (Canada)	242	Steenkampskraal
Greenland Minerals and Energy, Ltd. (Australia)	230	Kvanefjeld
Quest Rare Minerals, Ltd. (Canada)	180	Strange Lake (B Zone)
Tasman Metals, Ltd. (Canada)	154	Norra Karr
Stans Energy Corp. (Canada)	130	Kutessay II
Ucore Rare Metals, Inc. (Canada)	71	Bokan (Dotson / I & L Zones)

The economic feasibility of a particular rare earth project can also be affected by the existence of byproducts during extraction. Because rare earth elements appear naturally in different combinations within a single mineral form, mining for rare earths alone may be uneconomical, especially if the mineralogy favors some of the more abundant light rare earth elements (LREEs) instead of the more profitable heavy rare earth elements (HREEs). Even with prices at historic highs for most rare earth elements, some pure play rare earth projects may be less attractive to investors due to the lack of

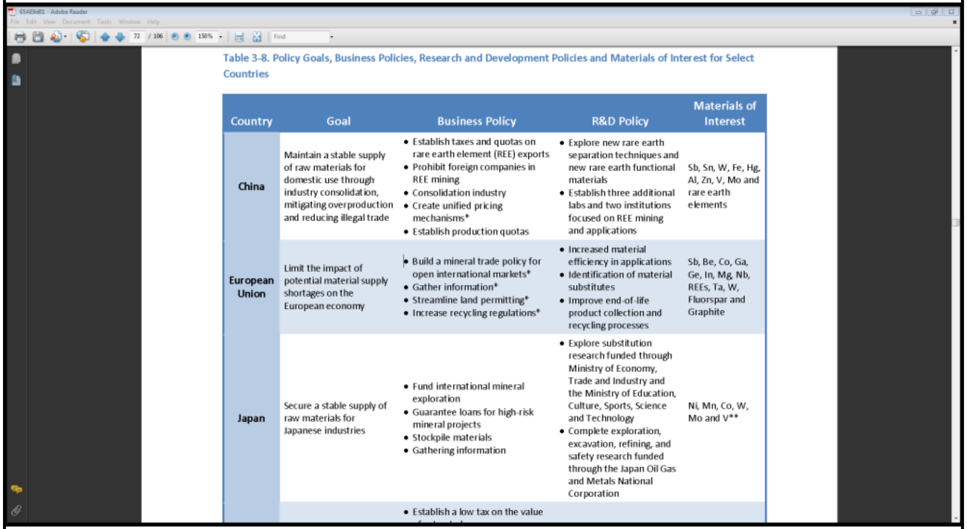


Table 3-8. Policy Goals, Business Policies, Research and Development Policies and Materials of Interest for Select Countries

Country	Goal	Business Policy	R&D Policy	Materials of Interest
China	Maintain a stable supply of raw materials for domestic use through industry consolidation, mitigating overproduction and reducing illegal trade	• Establish taxes and quotas on rare earth element (REE) exports • Prohibit foreign companies in REE mining • Consolidation industry • Create unified pricing mechanisms* • Establish production quotas	• Explore new rare earth separation techniques and new rare earth functional materials • Establish three additional labs and two institutions focused on REE mining and applications	Sb, Sn, W, Fe, Hg, Al, Zn, V, Mo and rare earth elements
European Union	Limit the impact of potential material supply shortages on the European economy	• Build a mineral trade policy for open international markets* • Gather information* • Streamline land permitting* • Increase recycling regulations*	• Increased material efficiency in applications • Identification of material substitutes • Improve end-of-life product collection and recycling processes	Sb, Be, Co, Ga, Ge, In, Mg, Nb, REEs, Ta, W, Fluorspar and Graphite
Japan	Secure a stable supply of raw materials for Japanese industries	• Fund international mineral exploration • Guarantee loans for high-risk mineral projects • Stockpile materials • Gathering information	• Explore substitution research funded through Ministry of Economy, Trade and Industry and the Ministry of Education, Culture, Sports, Science and Technology • Complete exploration, excavation, refining, and safety research funded through the Japan Oil Gas and Metals National Corporation	Ni, Mn, Co, W, Mo and V**
		• Establish a low tax on the value		

DOD Rare Earth Resources

2011 Joint Force Quarterly Article

its exports. China dramatically restricted its exports by 72 percent in the last 6 months of 2010 to satisfy its rapidly expanding national appetite for REEs.[2] China is also progressively acquiring the industrial base to manufacture permanent magnets and their end products at the expense of American businesses, which China systematically purchases and relocates within its borders. The entire supply chain of REE permanent magnets is now in China.[3]

As the American military and industrial sectors continue their move toward increased reliance on miniaturized high-performance electronics and strive to adopt more energy-efficient technologies, there are concerns that the United States may trade its reliance on Middle East oil for dependence on REEs from China. This article illustrates how REEs have become a deeply ingrained need throughout the American economy and, in particular, how rare earth magnets are now indispensable to the defense industry. It also explores how the United States should react to a threat to its lead in the technological innovation of military applications that use permanent magnets.

Colonel Justin C. Davey, USAF, wrote this essay while a student at the Air War College. It won the 2011 Secretary of Defense National Security Essay Competition.

REE mining and refining firms. It is critical

there are concerns that the United States may trade its reliance on Middle East oil for dependence on REEs from China

the government also be on guard against further sale and export of such U.S. companies to China. Simultaneously, the United States should continue funding research into permanent magnets using alternative materials that could balance the demand for REEs.

Rare Earth Elements

REEs have been described as "vitamins of modern industry" because of their necessity and wide application across the fields of energy, defense, and computer technology.[4] However, they are scarcely familiar to the general public. There are 17 minerals in the family of REEs: 15 from the chemical group known as lanthanides, plus scandium and yttrium.[5] These elements share similar geochemical characteristics and are qualitatively comparable to the chemistry of aluminum.[6] However, the slight variances in atomic structure between the REEs yield diverse optical, electrical, metallurgical, and magnetic properties that lend themselves to

standing and indifference that characterizes public perception. REEs are actually relatively abundant throughout the Earth's crust, about the same as some major industrial metals (copper, zinc, and chrome) and even greater than several precious metals (gold, silver, and platinum).[7] Nevertheless, these deposits are not concentrated, at most ranging up to a few hundred parts per million by weight. Although REEs are present in most massive rock formations and sources exist around the world, such low concentrations make the mining and recovery processes difficult and expensive. Nor can the industrial base required for production be created quickly. From the time a deposit is discovered, it takes 10 to 15 years of development and construction of the infrastructure needed to establish a full-scale REE recovery operation.[8] Consequently, it will require long-term vision and immediate action to wean the United States from its almost total dependence on foreign sources as world competition for REEs escalates.

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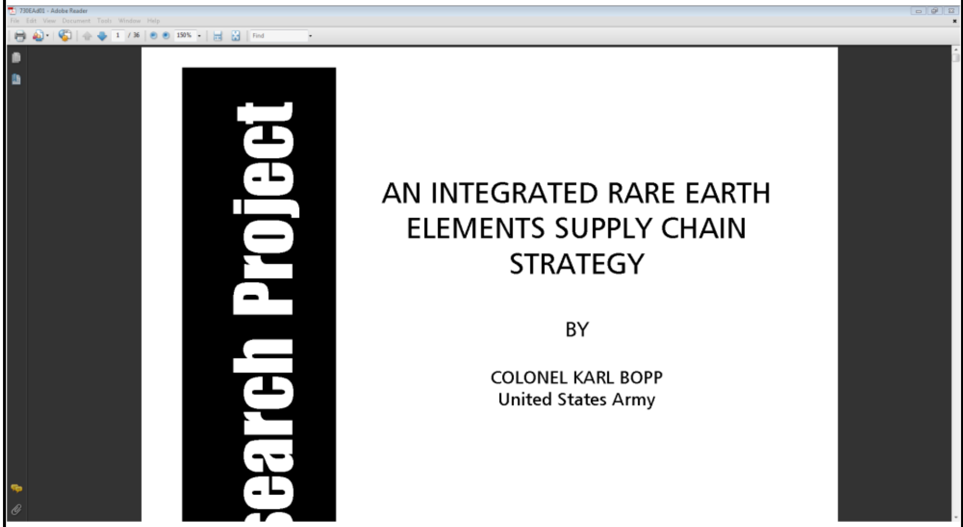
have over 10 times the magnetic energy product.[14] Accordingly, a much smaller amount of magnet is required for any particular application. This attribute makes them ideal for miniaturization of motors, electronics, and electrical components, including possible nanotechnologies.[15] The advent of these tiny, powerful magnets ushered in the era of the Sony Walkman, personal laptop computer, and more.

Permanent Magnets

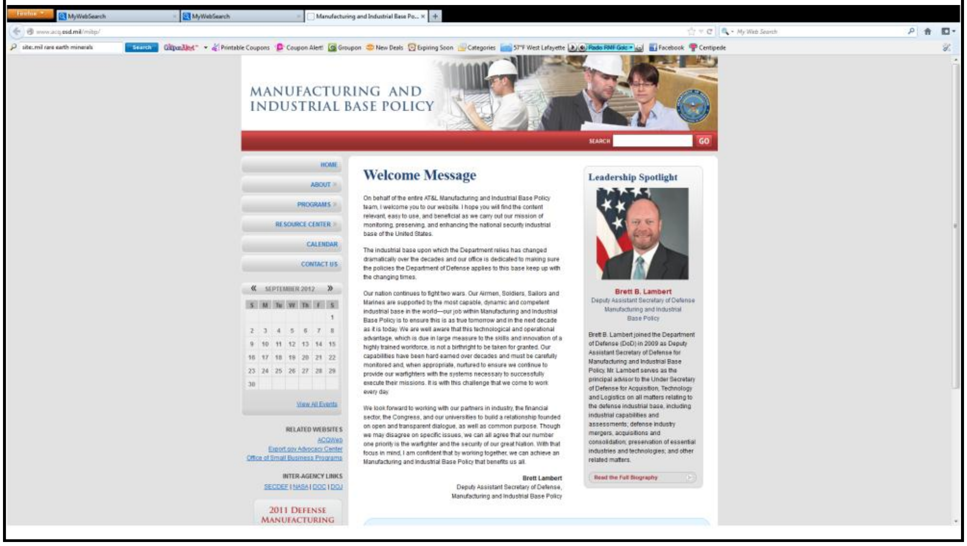
NdFeB and SmCo magnets are ingrained in the commercial high-tech, automotive, and energy markets of the United States. For instance, miniaturized multi-gigabyte disk and DVD drives, a mainstay in portable computers, are not possible without such magnets.[16] Those electronics are also used in automobiles for pollution-controlling catalytic converters and hybrid car engines—high-temperature environments where regular magnets would rapidly fail. Moreover, the use of REE magnets reduces

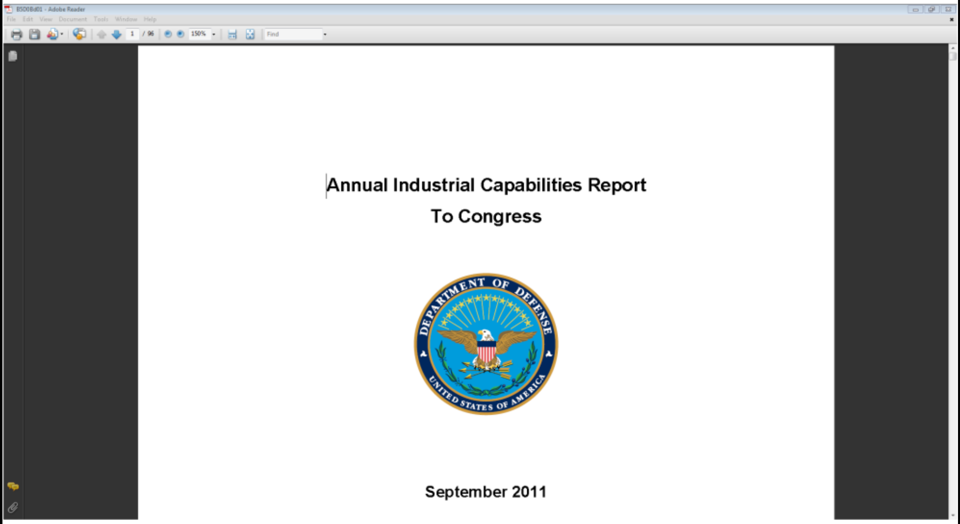
China's Rare Earth Elements Industry: What Can the West Learn?

By Cindy Hurst



Deputy Asst. Sec. Defense for Manufacturing & Industrial Base Policy

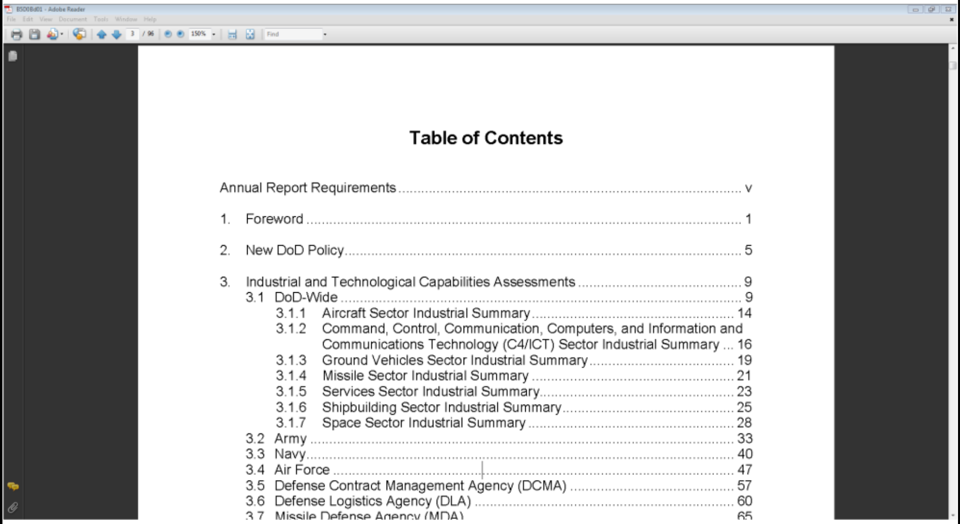




Annual Industrial Capabilities Report

To Congress

September 2011



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Rare Earth Materials Assessment (August 2010)

In April 2010, the Defense Contract Management Agency – Industrial Analysis Center (DCMA-IAC) was tasked to support a Rare Earth (RE) Materials Assessment for the Office of the Deputy Assistant Secretary of Defense for Manufacturing & Industrial Base Policy (ODASD) (MIBP)[1]. The purpose of the assessment was to determine the true domestic capabilities to reduce RE oxides to metals including companies that could reduce RE oxides to metals if necessary. DCMA-IAC's report was used to address vulnerabilities in the RE supply chain including recommendations to mitigate potential risks of supply disruption, as well as material pricing trends.

RE materials (ores, oxides, metals, alloys, semi finished RE products, and components containing RE materials) are used in a variety of commercial and military applications, and their availability worldwide is limited to only a few domestic and global sources. The Department relies on RE materials in the production of many of its weapon systems and needs to ensure their continued availability to meet national security objectives and military superiority.

Currently, China supplies approximately 97 percent of the world's RE, and has been gradually reducing its RE exports to the rest of the world as its own internal demand for RE increases. In spite of increasing RE global demand, export quotas from

[1] As of February 2011, the ODASD (Industrial Policy) is now the ODASD for Manufacturing & Industrial Base Policy (MIBP).

10

Foreign Sources of Supply

FY 2007 Report

Annual Report of United States Defense Industrial Base Capabilities and Acquisitions of Defense Items and Components Outside the United States.

Report Required by Section 812 of the National Defense Authorization Act for Fiscal Year 2004 (Public Law 108-136), as amended by Section 841 of the John Warner National Defense Authorization Act for Fiscal Year 2007 (Public Law 109-364)

4. **Assessment of Foreign Dependency**

The Department incorporates foreign items and components into many important systems, and in some cases the Department may be dependent upon foreign suppliers for these items. However, this does not mean the Department suffers from a foreign vulnerability. Foreign dependence usually does not equate to foreign vulnerability. The Department is not vulnerable if it is dependent on reliable foreign suppliers, just as it is not vulnerable when it is dependent on reliable domestic suppliers. Foreign vulnerability would occur only if the Department was dependent upon suppliers from a single or small group of countries that had the capability and political will to halt shipments to DoD in time of need, and when such delivery denial would cause direct and unacceptable impact to operations. In short, for there to be a foreign vulnerability, DoD must be dependent upon the foreign source (no alternative sources available or that could rapidly become available), and there must be a significant, creditable, and unacceptable risk of supply disruption due to political intervention by the host country or countries.

DoD Handbook 5000.60-H, "Assessing Defense Industrial Capabilities" identifies conditions in which reliance on foreign suppliers for specific products may constitute unacceptable foreign vulnerabilities.

- Foreign sources may pose an unacceptable risk when there is a high "market concentration" combined with political or geopolitical vulnerability. For example, a sole source foreign supplier existing only in one physical location and vulnerable to serious political instability may not be available when needed. (Market concentration alone is not sufficient reason to exclude foreign sources; there also must be a credible threat of supply disruption due to political instability. Sheer physical distance from the U.S. is also not by itself a risk which merits foreign source exclusion.)
- Suppliers from politically unfriendly or anti-American foreign countries, as defined by statute or U.S. Government policy, are not used to meet U.S. defense needs.[7]

[7] Countries categorically excluded from DoD contracts are countries listed as "terrorist countries" by the Secretary of State under 50 USC App. 2405(j)(1)(A) and countries subject to sanctions implemented by the Department of Treasury Office of Foreign Asset Controls (OFAC).

Congressional and Congressional Support Agency Resources

112TH CONGRESS
1ST SESSION

H. R. 1388

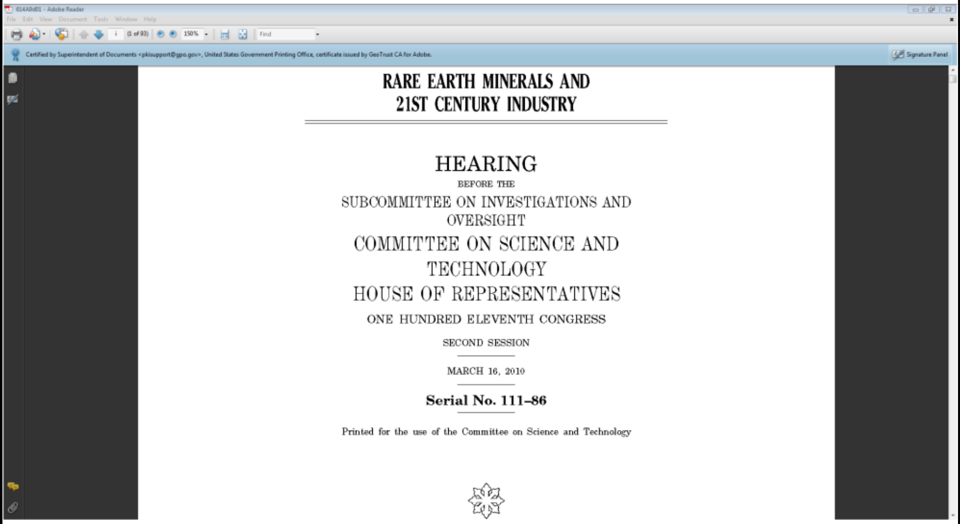
To reestablish a competitive domestic rare earths minerals production industry; a domestic rare earth processing, refining, purification, and metals production industry; a domestic rare earth metals alloying industry; and a domestic rare-earth-based magnet production industry and supply chain in the Defense Logistics Agency of the Department of Defense.

IN THE HOUSE OF REPRESENTATIVES

APRIL 6, 2011

Mr. COFFMAN of Colorado (for himself, Mr. PETERS, Mr. LATTA, Mrs. LUMMIS, and Mrs. MCMORRIS RODGERS) introduced the following bill; which was referred to the Committee on Science, Space, and Technology, and in addition to the Committees on Natural Resources and Armed Services, for a period to be subsequently determined by the Speaker, in each case for consideration of such provisions as fall within the jurisdiction of the committee concerned

A BILL



RARE EARTH MINERALS AND
21ST CENTURY INDUSTRY

HEARING

BEFORE THE

SUBCOMMITTEE ON INVESTIGATIONS AND OVERSIGHT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

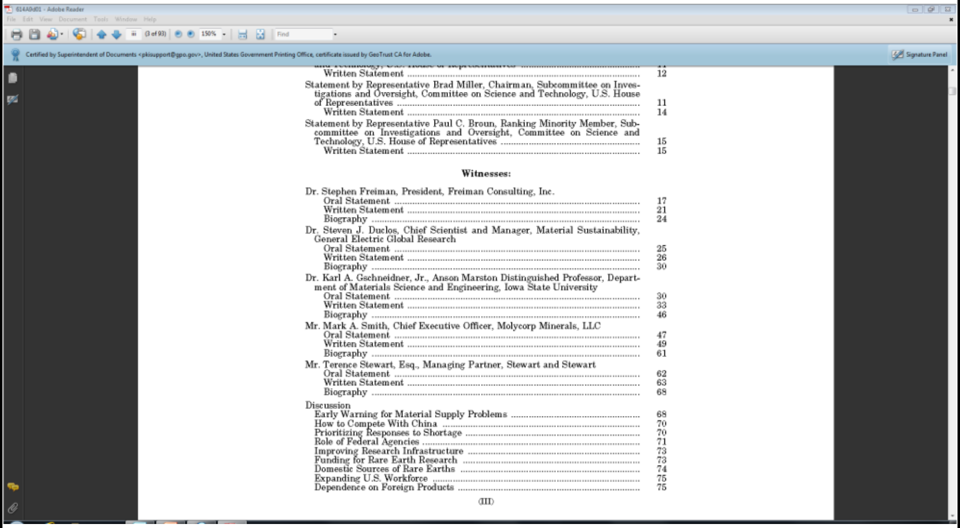
ONE HUNDRED ELEVENTH CONGRESS

SECOND SESSION

MARCH 16, 2010

Serial No. 111–86

Printed for the use of the Committee on Science and Technology



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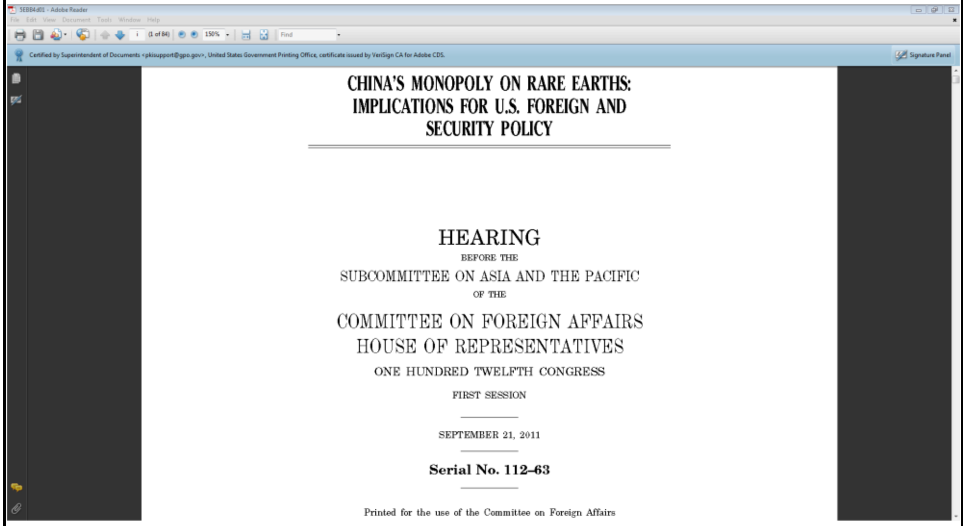


CHINA'S MONOPOLY ON RARE EARTHS: IMPLICATIONS FOR U.S. FOREIGN AND SECURITY POLICY

HEARING

BEFORE THE

SUBCOMMITTEE ON ASIA AND THE PACIFIC

OF THE

COMMITTEE ON FOREIGN AFFAIRS

HOUSE OF REPRESENTATIVES

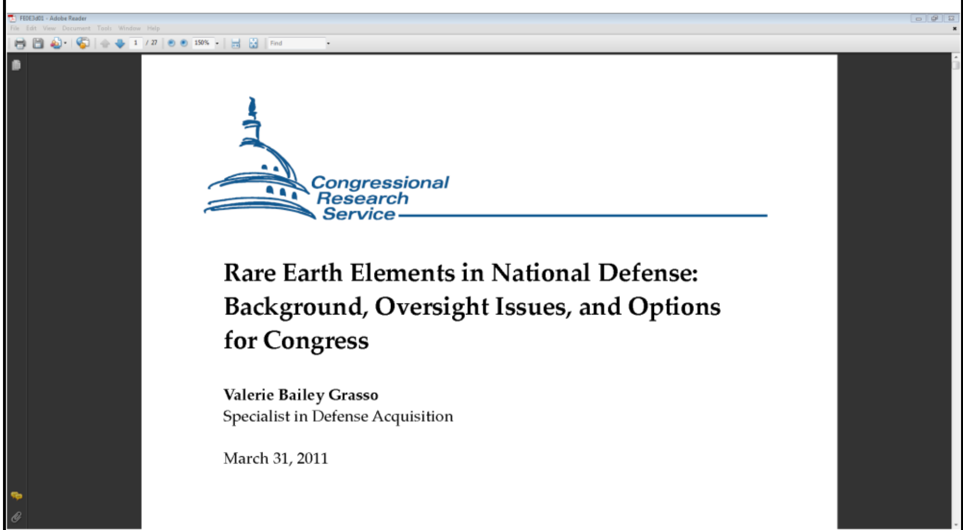
ONE HUNDRED TWELFTH CONGRESS

FIRST SESSION

SEPTEMBER 21, 2011

Serial No. 112–63

Printed for the use of the Committee on Foreign Affairs



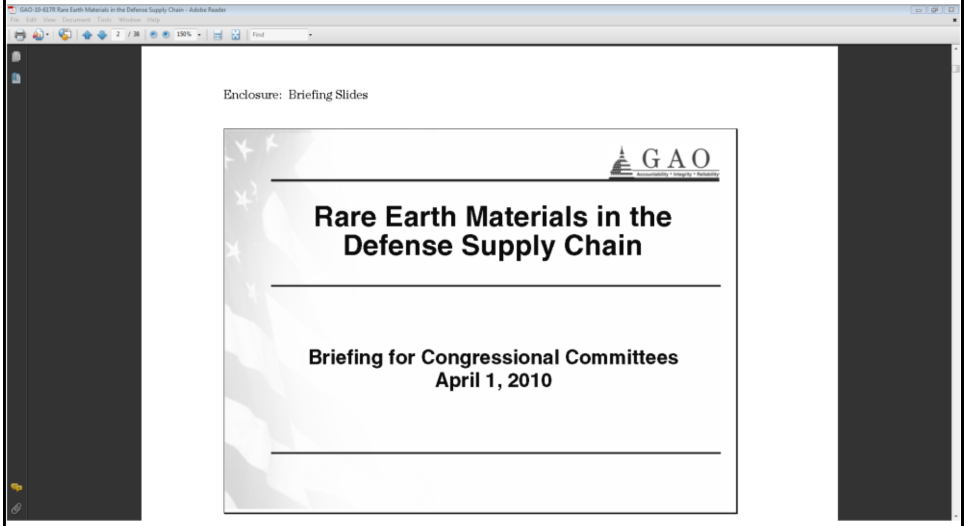
Congressional Research Service

Rare Earth Elements in National Defense: Background, Oversight Issues, and Options for Congress

Valerie Bailey Grasso

Specialist in Defense Acquisition

March 31, 2011

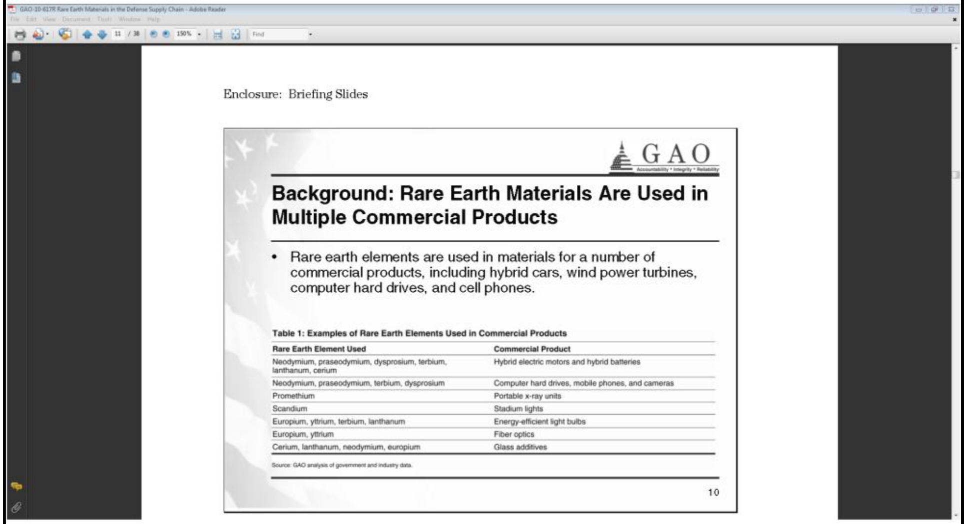

Enclosure: Briefing Slides

GAO

Accountability * Integrity * Reliability

Rare Earth Materials in the Defense Supply Chain

Briefing for Congressional Committees
April 1, 2010


Enclosure: Briefing Slides

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Accountability * Integrity * Reliability

Background: Rare Earth Materials Are Used in Multiple Commercial Products

- Rare earth elements are used in materials for a number of commercial products, including hybrid cars, wind power turbines, computer hard drives, and cell phones.

Table 1: Examples of Rare Earth Elements Used in Commercial Products

Rare Earth Element Used	Commercial Product
Neodymium, praseodymium, dysprosium, terbium, lanthanum, cerium	Hybrid electric motors and hybrid batteries
Neodymium, praseodymium, terbium, dysprosium	Computer hard drives, mobile phones, and cameras
Promethium	Portable x-ray units
Scandium	Stadium lights
Europium, yttrium, terbium, lanthanum	Energy-efficient light bulbs
Europium, yttrium	Fiber optics
Cerium, lanthanum, neodymium, europium	Glass additives

Source: GAO analysis of government and industry data.

10

U.S.-China Economic and Security
Review Commission Staff Backgrounder

China's Rare Earths Industry and its Role in the International Market

Lee Levkowitz, Policy Analyst
Nathan Beauchamp-Mustafaga, Research Intern

November 3, 2010

Introduction

China produces 97 percent of the world's rare earth elements, a key component in a large assortment of advanced military and civilian technologies. Increasing global demand and Chinese reductions in export quotas over the past six years have led to international concerns about future supply shortages. Although the United States currently is seeking alternative sources for rare earths, the Government Accountability Office has stated that it may take up to 15 years before the United States is able to rebuild its U.S.-sourced rare earth supply chain.[1] In addition, China's monopoly over rare earths has led to fears of China using its dominance as leverage to influence other nations' foreign policies. The following backgrounder seeks to provide an overview of China's rare earth industry and how it affects the United States.

What Are Rare Earth Elements?

Rare earth elements are a collection of 17 elements that are critical to civilian and military high technology applications.[*] Rare earth elements are distributed globally, with 36 percent of known

weapons and equipment that contain rare earths are: Predator unmanned aerial vehicles, Tomahawk cruise missiles, Zumwalt-class destroyers, night vision goggles, smart bombs, and sonar transducers.[7] Nevertheless, a November 2010 Department of Defense report found that the U.S. military consumption of rare earth elements constitutes less than five percent of overall U.S. consumption.[8]

(For more information about the rare earth elements and their applications, see Appendix A.)

History of the Rare Earths Industry

While China dominates the rare earth production market today, the United States was once the world leader in rare earth production and innovation. From the 1950s until the 1980s, the United States was the number one producer and innovator for rare earth elements in the world, with most mining taking place at the facility in Mountain Pass, located near the Nevada border in the Mojave Desert of southeastern California. In 1984, the Mountain Pass mine accounted for 100 percent of U.S. domestic demand and one-third of global exports of rare earths.[9]

As the United States was leading the world's rare earth industry, leaders in Beijing began to realize China's potential to exploit its own abundant rare earth reserves; Deng Xiaoping allegedly stated in 1992, "There is oil in the Middle East; there are rare earths in China."[10] In the late 1970s, China's production capacity dramatically increased due to government support for developing enhanced mining techniques and research and development (R&D) for rare earth applications.[†,11] As a result, China averaged a 40 percent increase in rare earth production annually from 1978 to 1989, making it one of the world's largest producers. Most of China's rare earth mining has centered around China's Bayan Obo mine in Baotou, Inner Mongolia.

During China's build up of its domestic rare earth production capacity, many Chinese rare earth mining companies were not profitable, but were able to continue operations due to non-performing loans and other forms of financial support from Chinese government-controlled banks.[12] This support allowed Chinese rare earth companies to produce at low prices, thereby increasing exports of rare earths. China's increasing exports through the 1990s caused global prices to fall considerably, eventually driving non-Chinese producers out of business. The California-based Mountain Pass mine shut down in 2002 primarily as a result of lower-priced competition from Chinese suppliers, leaving the United States entirely dependent on imports for its domestic rare earths consumption.[13]

As mining of rare earth elements moved from the United States to China, production of rare earth oxides, alloys and permanent magnets used for many of the above-listed commercial and military applications moved to China as well. The relocation of production to China has resulted in the United States relinquishing its position as the leading country for research in rare earth technologies. Rare earths industry consultant Jack Lifton has stated that even if the United States was able to resume rare earth mining immediately, the erosion of technical expertise would leave U.S. producers unable to effectively refine rare earths into usable materials, and a lack of experienced researchers would significantly hinder U.S. commercial and military innovation in rare earths products.[14]

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Questions